

Sedimentology: Description (GEOLOGY OF USSR, 1970) – thickness of Callovian–Upper Jurassic deposits is not higher than 50 m. They are presented at the cupola of anticlines. At the most parts of Mountain Mangyshlak (Fig. AS1A) mentioned rocks are missing and Lower Cretaceous sediments cover Pre-Callovian Middle Jurassic deposits. Within Mangyshlak Penninsula Callovian – Kimmeridgian rocks are determined. Presence of Tithonian deposits is still discussed.

Lower Callovian rich in fossils (brachiopods, bivalves and ammonites) rocks are presented by dark gray and greenish gray clays with subordinate carbonate sandstones and sandy limestones sometimes with plant remnants with few species of ammonites of *Keplerites* genus, including index species – *Keplerites goverianus* Sow. Thickness is 10–15 m.

Boundary between Lower and Middle substages is marked by abrupt decrease of volume of plant detritus typical for Sarydiirmen(skaya) Fm. of Middle Jurassic.

Middle Callovian deposits are presented by bluish–gray cloddy intensively sandy and ferruginous rich in fossils (brachiopods, corals, bivalves and ammonites) limestones, called “rusty horizon”. Ammonites of genus: *Stephanoceras*, *Perisphinctes* and *Kosmoceras* are rarely met. Foraminifers *Lenticulina cultratifomis* Mjatl., *L. catastrophum* (Mitijan), *L. polonica* (Wishn.), *L. erucaeformis* (Wishn.) occur. Thickness varies from 1 to 17 m.

Upper Callovian gray gypsum-bearing rich in fossils (bivalves and ammonites) sands contain shells of ammonites of genus: *Quenstedticeras*, *Peltoceras*

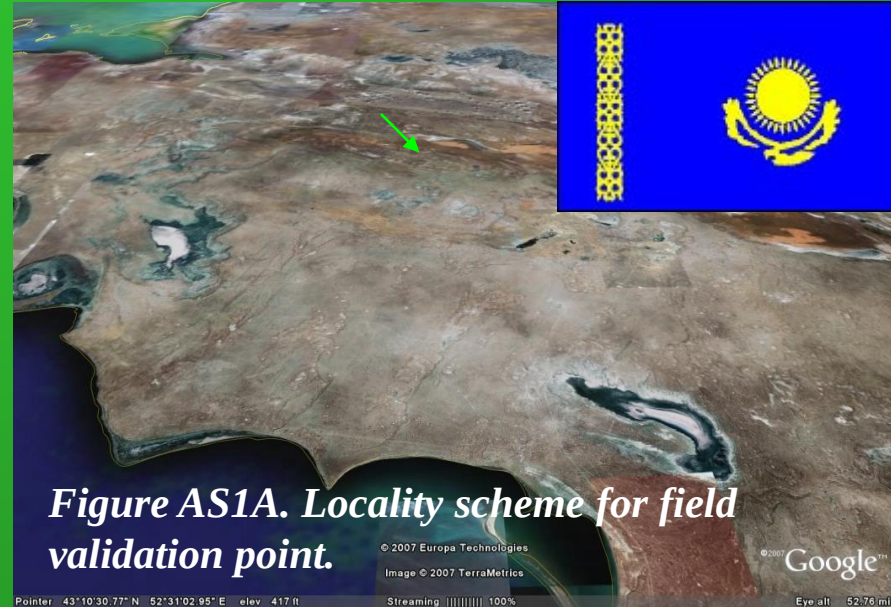


Figure AS1A. Locality scheme for field validation point.

Locality 1: Mangyshlak Penninsula, Mesgistaus(skaya) province, SW Kazakhstan
Position (determined by Google Earth):

44.54.01.28 N, 52.24.01.06 E

Age: Callovian–Kimmeridgian

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within Turan Plate

Petroleum systems information is given at §6

and *Kosmoceras*. Foraminifers *Textularia depravata* (Schwag.), *Lenticulina tumida* Mjatl., *L. calva* (Wisn.), *L. hoplites* (Wisn.), *Planularia colligata* (Bruckm.), *Frondicularia supracalloviensis* (Wisn.), *Epistomina* aff. *mosquensis* Uhlig. and others. Thickness varies from 14 to 20 m.

Oxfordian deposits have a distinctive boundary with Callovian ones and are presented by greenish-gray marls transiting into clayey limestones or into carbonate clays. Boundary between Lower and Upper Oxfordian is characterized by change in foraminifers assemblage and by finds of *Cardioceras suessifirmis* Spath (J_3ox_1) and *Amoeboceras* cf. *alternans* (Buch.) (J_3ox_2). Thickness of **Lower Oxfordian** varies from 48 to 137 m at wells and 6–7 m in exposures. Thickness of **Upper Oxfordian** varies from 45 to 137 m at wells and 0.5–13 m in exposures.

Kimmeridgian rocks with clearly seen gap cover Oxfordian sediments. In wells one could see hard limestones with re-crystallized bivalve shells and innumerable foraminifers *Lenticulina* ex gr. *infravolgensis* (Furss. et Pol.), *L. aff. muensteri* (Roem.), *Vagonulina raricostata* (Furss. et Pol.), *Tristix temirica* (Dain.) and others. Also **Upper Kimmeridgian** bivalves *Exogyra virgula* Goldf., *Loripes* cf. *costromensis* Geras., *Astarte* cf. *pontica* Pcel. Upper units do not contain fossils and boundary with Valanginian rocks is positioned conventionally by decrease of limestone density. At exposure above eroded surface of Oxfordian clays light gray hard sandy at the base with small portion of pebble and gravel limestones of 4 m thick with shells of *Alectryonia* sp., *Rhynchonella* sp., *Terebratula* sp. and others are lying. Described above deposits can be observed within Zharmysh area near Sarydiirmen Mt.

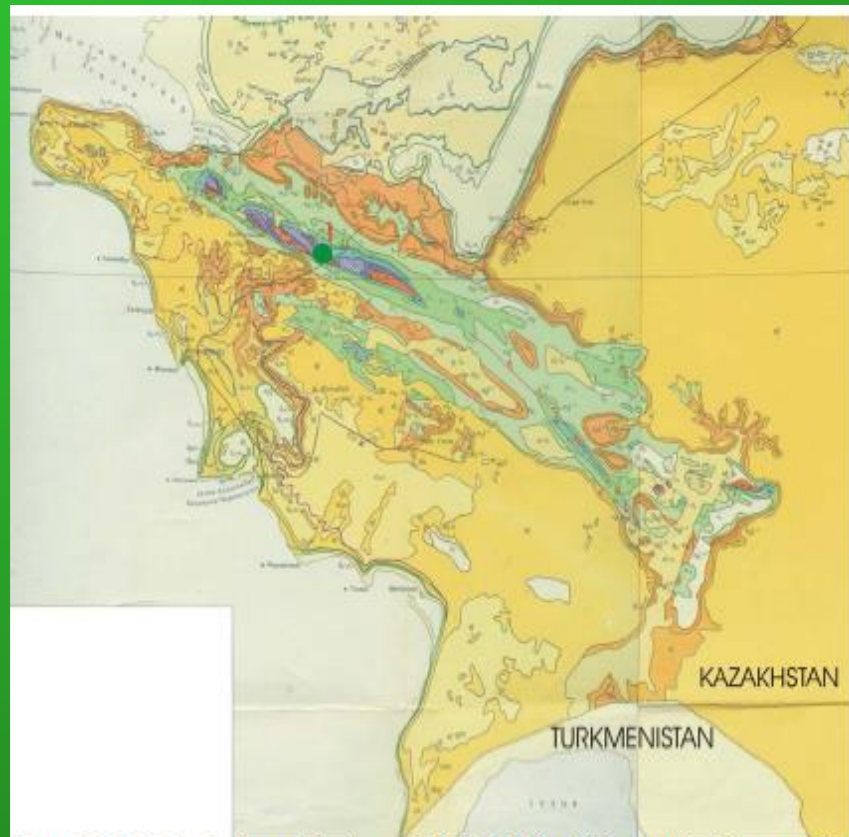


Figure 2.2.8. Geological map (Geology of USSR, 1970) of Western Kazakhstan with position of field validation point no. 1.

Sedimentology: Description (GEOLOGY OF USSR, 1970)

– Callovian–Upper Jurassic sequence with unconformity lies upon different horizons of Middle Jurassic.

Characteristics of Callovian – Lower Oxfordian interval of the sequence is given in details on Table 3.2. Below a brief description will be given.

Usually Callovian – Lower Oxfordian interval of the section is exposed at Tuarkyr (Fig. AS2A, B). **Lower Callovian** is mainly presented by clays with subordinate beds and lenses of siltstones, carbonate sandstones, sands and sandy limestones. Thickness of this substage is irregular and varies from 2.5 to 35 m. Fossils are rarely met. **Middle Callovian** consists of alternation of clay and clayey siltstone with lentic beds of light gray silty limestone containing rich fossil complex. Thickness is unstable and can reach 35 m. **Upper Callovian** deposits (up to 40 m) are presented by clays mainly carbonate with beds and lenses of limestones and marls. Above purple silty and clayey limestones, facially transiting into dolomites. At Beyney anticline (South of Tuarkyr area) section of Callovian is condensed: Lower and Middle Callovian deposits are missing and Upper Callovian limestones and siltstones of 6 m thick contain Lower-, Middle- re-deposited and Upper Callovian fossils.

Oxfordian Stage is presented by Lower substage that conformably covers Upper Callovian rocks. The maximal thickness of remained Lower Oxfordian after Early Cretaceous erosion is 46 m. At Beyney anticline Lower

Oxfordian with erosion covers Upper Callovian



Locality 2: Tuarkyr Plateau, Balkhan welayaty, NW Turkmenistan
Position (determined by Google Earth):
40.40.58.00 N, 55.23.57.19 E

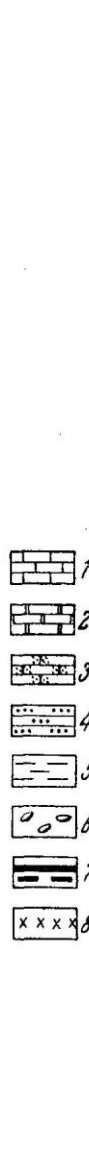
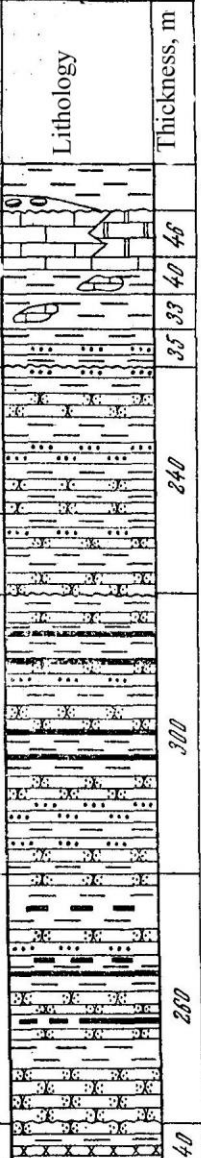
Age: Callovian – Lower Oxfordian

Interpretation - Shallow-marine environment.

Structure: Callovian – Upper Jurassic deposits of Tuarkyr comprise a monocline limiting the eroded central part of Tyarkyr anticline

Regional significance: This validation point belongs to Tyarkyr anticline located within Turan Plate
Petroleum systems information is given at §6

Stage		Lithology	Thickness, m
Substage			
L. Cret.			
Oxf.	L.		48
	L. M.		33
	U.		40
	L. M.		35
Bathonian			240
L.			
UPPER			
Bajocian			300
Aalenian			280
L. J.			40



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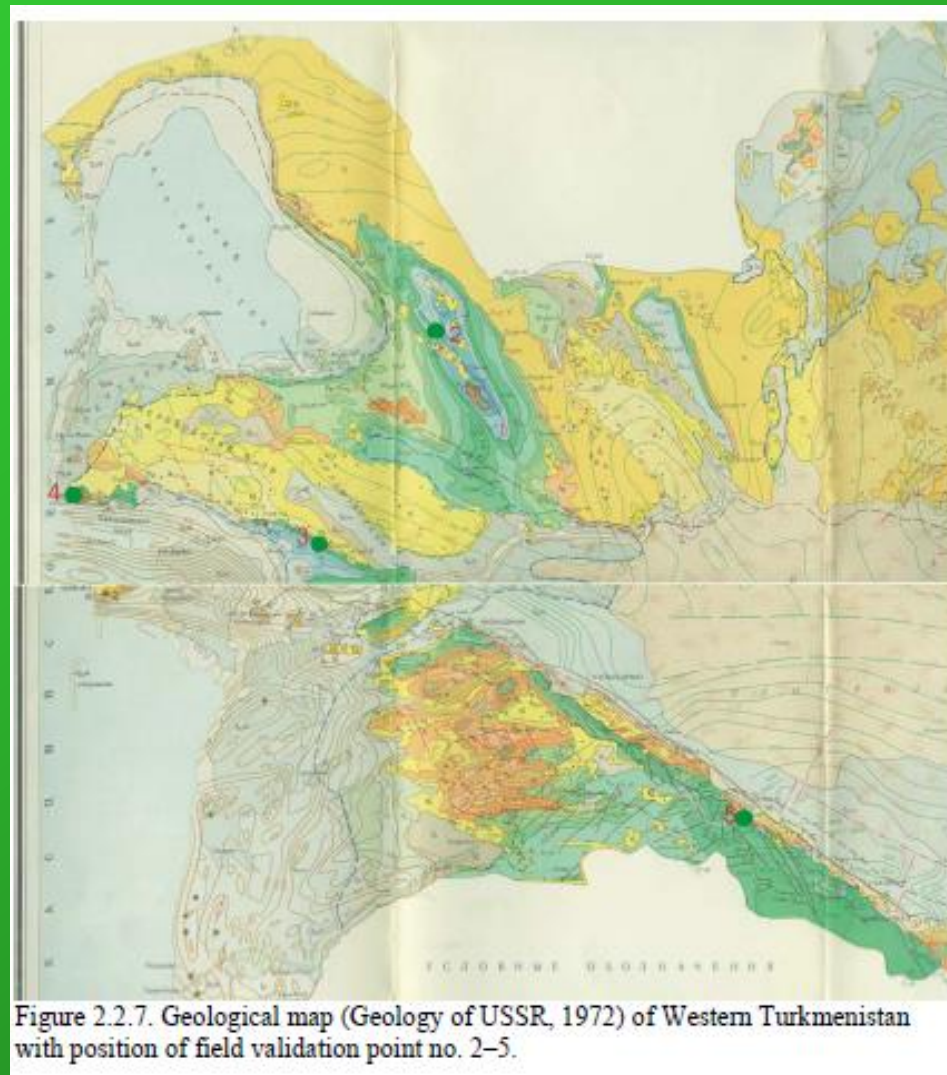


Figure 2.2.7. Geological map (Geology of USSR, 1972) of Western Turkmenistan with position of field validation point no. 2-5.

Fig. AS2B. General section of Tyarkyr (Geology of USSR, 1972): 1 – limestones; 2 – dolomites; 3 – sandstones; 4 – siltstones; 5 – clays; 6 – conglomerates; 7 – coal; 8 – bauxite-like rock.

Sedimentology: Description (mostly from: Beznosov, Mitta, 2000) – Great Balkhan (Figs. AS3A–C) unites a complex of outcrops of Callovian – Upper Jurassic deposits demonstrating strong facial variety. Middle Jurassic and Lower Cretaceous rocks here are well exposed too. It is a unique place to study stratigraphy (lots of fossils), sedimentology (perfect outcrops, different facies and facies associations) and as a result – paleogeography. Below a review of geology of Great Balkhan area is given.

Koshadjulbin(skaya) Fm. (Upper Bathonian – herveyi zone of Lower Callovian).

Koshadjulbin(skaya) Fm. was described by N.V.Beznosov, Yu.L.Verba, G.Ya. Krymgoltz in 1975. It with angular unconformity overlay upon Seutlyn(skaya) Fm. and Upper and Lower SubFm. of Meulam(skaya) Fm. At the Northern wing of Great Balkhan anticlinorium it is discontinuously distributed within cores of Pre-Cretaceous from foot of Irtykburun Mt. at the West to Porsukh Mt. at the East. At the South it's exposures frame Western foots of cliffs of the Western part of Great Balkhan ridge to the West from Arlan Mt. and is traced up to Western foot of Shakhliburun Ridge. Fm. exposes at Tashlydere Gorge at Se of Great Balkhan. At SE slope of Koshadjulba Mt. describing Fm. with unconformity covers Lower Meytlam(skaya) subFm. Here the following section is exposed.

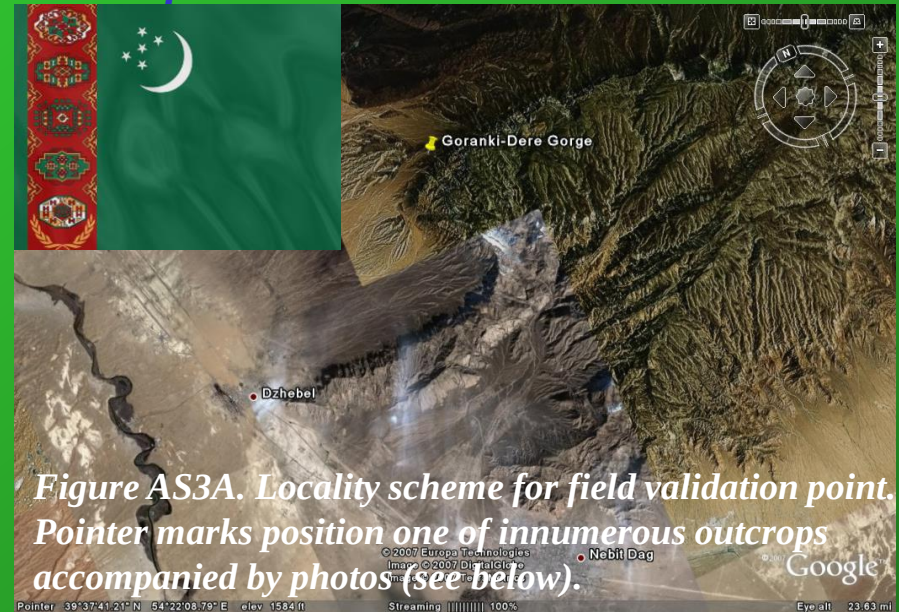


Figure AS3A. Locality scheme for field validation point. Pointer marks position one of innumerable outcrops accompanied by photos (see below).

Locality 3: Bolshoy (Great) Balkhan Plateau, Balkhan welayaty, NW Turkmenistan

Position (determined by Google Earth):

39.42.49.06 N, 54.23.49.02 E

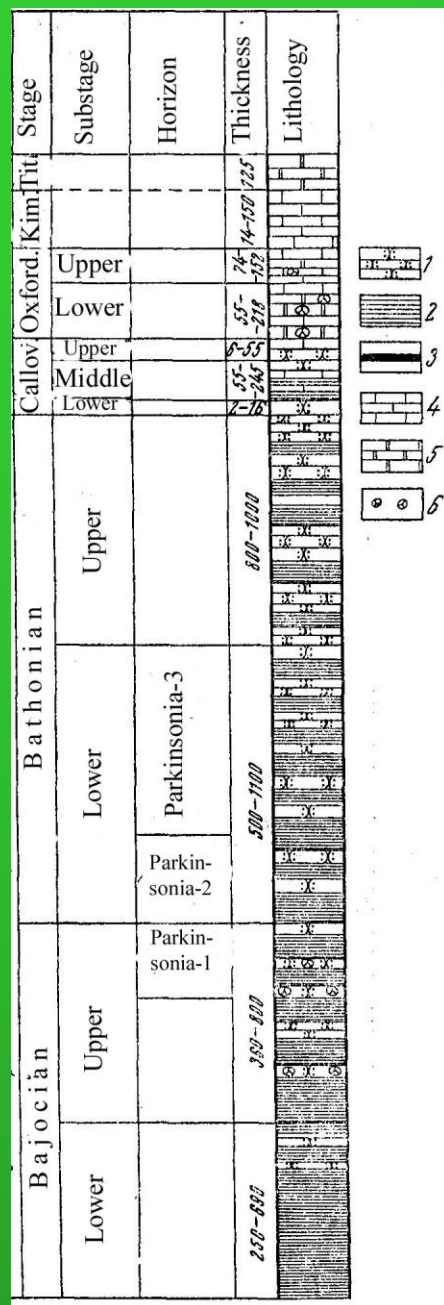
Age: Callovian–Titonian

Interpretation - Shallow-marine, lagoon and continental environment.

Structure: Callovian–Upper Jurassic deposits built up wings of Great Balkhan anticline. Wings are complicated by small folds. The most complete sections of describing interval belong to synclines (Guide-book., 1961).

Regional significance: This validation point is located within Great Balkhan anticline belonging to Turkmen-Kharasan folded system

Petroleum systems information is given at §6



1) Quartz gravelites inside sandy-clayey detritic limestone matrix (0.5 m), to the top transiting into alternation of sandy-silty cloddy with sandy detritic limestones with distributed within rock quartz gravel. Thickness decreases to the East till total disappearance of Fm. under the top of Koshadjulba Mt. 30 m.

2) Light gray fine-grained carbonate sandstones with shell debris. 12 m. Thickness decreases under the top of Koshadjulba Mt., where sandstones become loose.

Figure AS3B. General section of Jurassic deposits of Great Balkhan (Geology of USSR, 1972): 1 – sandstones; 2 – argillites; 3 – coals and coaly shales; 4 – limestones; 5 – dolomites; 6 – concretions.

To the South at Upper parts of gullies coming down to Karaiman and Devona springs Koshadjubil(skaya) Fm. covers Seutlin(skaya) Fm. First unites:

1. Dark gray sandy-silty cloddy argillites alternating with subordinate gray detrital sandy limestones. At the base basal sandstone bed occurs. *Loboplanulites prosorovskii* Besnosov. Thickness 4–15 m.
 2. Bluish-gray silty argillites to the top transforming into clayey siltstones. 2–10 m.
 3. Light gray carbonate sandstones at the base alternating with clayey siltstones with abundant shell detritus. Subordinated detrital sandy limestone beds conclude innumerable fossilized echinoids and bivalves. 4–10 m.
- Here Fm. fills a syncline of NW extension. Thickness of Fm. and its members and beds decreases in direction from the axis of the fold within 150–200 m. The close composition can be observed at Southern foot of Bordjokly Ridge where thickness of members 1 and 2 is 15 and 3 m, consequently. At the Western foot of Irtykburun member 2 is transgressively cut by sandstones of Urumliujan(skiy) Horizon. Member 1 is presented by cloddy sandy siltstones with subordinate carbonate sandstone bed with quartz and rock pebble. Visual thickness of Fm. here is more than 15 m. *Prohecticoceras* sp.



Figure AS3C. View to Goranki-Dere Gorge, Djebel'-Ata area (Orimlidje section according to Beznosov, Mitta, 2000), Great Balkhan. 25.01.1993

Guzvash(skaya) Fm. (Middle Callovian)

Guzvash(skaya) Fm. was described by Yu.L.Verba, G.Ya. Krymgoltz, V.A. Prozorovskiy in 1976 and conformably covers Djebel-Ata (Djebel'atin(skaya)) Fm. It is distributed at the same areas as underlying Fm. But also it exposes at Tuezmergen Gorge.

At Bordjokly Chain section one could see:

- 1) Greenish-gray fine- and medium-grained quartz-feldspar sandstones. Relatively loose and hard types of rock are alternated. 50–60 m.
- 2) Light gray sandy, dolomitic siltstones with subordinated beds of dolomitic silty marls. 20–22 m.

Djebel-Ata (Djebel'atin(skaya)) Fm. (koenigi and calloviense zones of Lower Callovian)

Djebel-Ata (Djebel'atin(skaya)) Fm. was described by Yu.L.Verba, G.Ya. Krymgoltz, V.A. Prozorovskiy in 1976.

Djebel-Ata Fm. is distributed at the same regions as Koshadjulbin(skaya) Fm. excluding Eastern foot of Irtykburun Chain where it is cut down by rocks of Urumlidjan(skyi) Horizon. Fm. everywhere lies upon the eroded top of member 2 of Koshadjulbin(skaya) Fm. At the most Western exposures at Bordjokly Chain fm. is presented by:

1. Sliding greenish-gray clays with subordinated beds of bivalve shell rock and loose fine-grained sandstones. Thickness is 10–12 m.
2. Greenish-gray fine-grained not clearly bedded carbonated by spots sandstones. 3 m.
3. Sliding greenish-gray bedded sandy-silty clays irregularly alternated with loose greenish-gray fine-grained sandstones. Thickness is 6–7 m.
4. Gray fine-grained carbonate massive sandstones with small quartz gravel. 1.5 m.
5. Analog of bed no. 3. Thickness is 3 m.

The same composition characterizes Fm. in other sections of the northern wing of great Balkhan anticlinorium. The ratio of clays and sandstones and thickness of Fm. quickly change. Last at syncline of Koshadjulba Mt. varies from 20 to 60 m, at Gerkez Mt. from 90 to 100 m, at Oglanly Chain from 70 to 85 m.

Urumil'djan(skyi) Horizon (Upper Callovian – Oxfordian)

Urumil'djan(skyi) Horizon was described by N.V.Beznosov and V.V.Kutuzova in 1985 and with local erosion overlies Guzvash(skaya) Fm., transgressively covers lower member of Koshadjulbin(skaya) Fm. at Shakhliburun Chain and crystalline basement at Kubadag to the west from Great Balkhan. Horizon unites ***Irtykburun(skaya) unit, Ishekiol'(skaya) Fm., Tashlydere (Tashlyderin(skaya)) barrier reef Fm. and Ekerem(skaya) Fm.*** laterally transiting into each other (Figs. AS3D - F).

Irtykburun(skaya) unit. Unit is exposed at the Western slope of Irtykburun Mt. where it with erosion covers member 1 of Koshadjulbin(skaya) Fm. Unit is presented by light gray fine- and coarse-grained massive and thickly bedded sandstones with steep skew (slanting) bedding with skew lenses of gravelites and conglomerates. Thickness up to 100 m.

To the West from Irtykburun Chain sandstones disappear and basement rocks are covered by Lower Cretaceous (Dagada Island) or Neogene (Belek station area) rocks.

Analogous rocks are the part of Kaifatin(skaya) Fm. at the Eastern ending of Kubadag. Here they are 60-70 m thick.



Figure AS3D. Upper Callovian unit of alternation of sandstones and siltstones of Urumil'djan(skyi) Horizon. Goranki-Dere Gorge, Djebel'-Ata area (Orimlidje section according to Beznosov, Mitta, 2000), Great Balkhan. 20-25.01.1993

Ishekiol'(skaya) Fm

It is distributed at the Northern wing of Great Balkhan anticlinorium filling Pre-Cretaceous synclines at Bordjokly Chain, at Koshadjulba and Gerkez Mts. area, at Oglanly Chain and at Kyariz Mt. it is also distributed at Great Balkhan Ridge where it is from North to South and from foot to top facially transformed into reef buildings of Tashlydere Fm.

At the sections of Northern wing of Great Balkhan anticlinorium Fm is built from yellowish-gray medium-thickly bedded microcrystalline and micritic dolomites with rare bivalves. Thickness changes from 40 m at Bordjokly Chain to 12 m at Koshadjulba Mt. (where it is covered by Lower Cretaceous), to 45 m at Gerkez Mts. and to 60 m at Oglanly Chain.

At the Northern cliffs of Great Balkhan Fm. is exposed to the west from Arlan Mt. where it unites spotty dolomites and dolomitized thickly- and medium-bedded limestones with chert concretions at the middle and upper parts. Rock is full of spicula of siliceous sponges. Thickness reaches 180 m.

At the base of Fm. at Ekerem area *Indosphinctes* (*Indosphinctes*) aff. *rusticus* Spath, *I. (Elatmites?)* sp. were collected. From Great Balkhan among mentioned forms *Lima minima* Roll, *Kallirhynchia kiarisensis* Prosor occur. Bordjokly Chain conclude bivalve complex consisting from *Chlamys* cf. *fibrosus* Sow., *Inoperna sowerbyi* (d'Orb.), *Myophorella* cf. *signata* Ag., *Laternula vaulignigacensis* Lor. and others. Foraminifers *Marssonella doneziana* Dain, *Glomospira* sp., *Textularia jurassica* Gumb., *Verneuilinoides*, *Trochammina*, *Ammobaculites* spp., *Agatamina* cf. *antiqua* Said et Baracat, *Quinqueloculma* cf. *teresa* Danitch, *Lenticulina* sp., *Spirillina* aff. *kubleri* Mjatl. occur.



Figure AS3E. Terrigenous unit of alternation of sandstones and siltstones gradually passes into unit of carbonate sandstones. Upper Callovian. Urumil'djan(skyi) Horizon. Goranki-Dere Gorge, Djebel'-Ata area, Great Balkhan. 20-25.01.1993

Tashlydere (Tashlyderin(skaya)) barrier reef Fm.

Reef buildings are traced from Dagdirym Mt. at the West to Tashlydere Gorge at the East making a sublatitudinal stripe. They differ in size, position within sequence and complex of reef-building organisms.

The most lower position in the section at the base of Urumil'djan(skyi) Horizon is occupied by Tashlydere reef and buidings of central and Western parts of Shakhliburun ridge.

Tashlydere reef with erosion covers Guzvash Fm. and with unconformity is covered by Arlan(skaya) Fm. of Beriassian – Valanginian. The observed height of reef is 120–150 m, width – about 1 km. Reef is comprised by light massive limestones with biogermal bedding. Big size detritus including fragments of stromatoporates, bryozoans, corals cemented by algael incrustation and crystalline calcite prevail. Shakhliburun Ridge contain hill-shaped reef buildings of 30 – 40 m high and 100 m wide. At the base sometimes relicts of stromatoporates can be seen.

To the North from Ekerem area and in the middle part of Tuezmergen Gorge at the joining point of Chukansu and Inzhirlydyi Gorges foot of reefs is situated on different levels within lower half of Urumil'djan(skyi) Horizon covering the wedge of spotty dolomites and limestones of Ishekiol'(skaya) Fm. The most high reefs are 150 m high and their top reach to top of Horizon. Buildings consists of huge crystalline dolomites with chert concretions. In thin sections relicts of bryozoan fragments and abundant spicula of siliceous sponges can be seen. At the Upper part of Tuezmergen Gorge and at water parting area of Tuezmergen, Chukansu and Inzhirlydyi Gorges reefs migrate into the upper part of Horizon but become smaller commonly presenting small steep slope hills of 5-20 m high (maximal height is 70 m). they consist of micritic dolomitized limestones with relicts of algael textures and spicula of siliceous sponges.

From reefs of lower part of Horizon *Ammobaculites*, *Trochammina*, *Glomospira*, *Marssonella*, *Haplophragmoides*, *Ophthalmidium*, *Spirillina*, *Epistomina* spp. and big *Lithuoliidae* (?) were determined. From algael-spongal buildings of upper part of Horizon *Mansonella doneziana* Dam, *Verneuilinoidea*, *Spiroplectammina* spp, *Textularia jurassica* Gumb., *Ophthalmidium* ex gr. *carinatum* (Kubl. et Zw.), *Spirillina* sp., *Epistomina* cf. *volgensis* Mjatl., *E. ex gr. uhligi* Mjatl. were detected.

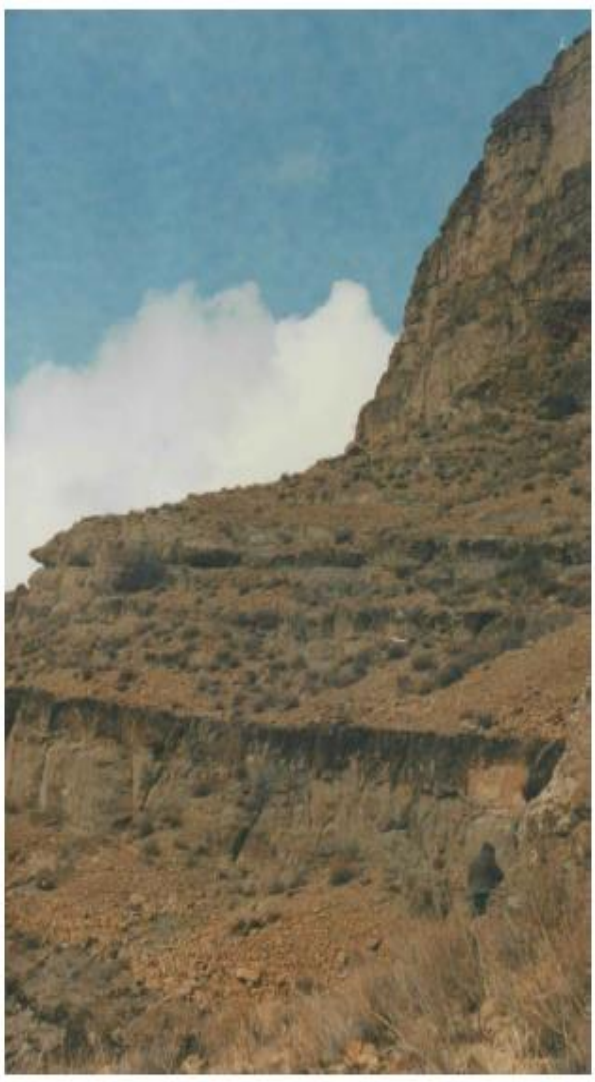


Figure AS3F. Terrigenous Upper Callovian units gradually passes into Oxfordian carbonate reef units forming vertical cliffs. Urumil'djan(skyi) Horizon. Goranki-Dere Gorge, Djebel'-Ata area, Great Balkhan. 20-25.01.1993

Ekerem(skaya) Fm.

Ekerem(skaya) Fm. totally comprise the section of Horizon to the South from Great Balkhan (Nebit-Dag G1 & Danata-1 wells). At Great Balkhan it is traced within Southern wing of anticlinorium where leans and bench-like replaces from North to South and from base to top reef buildings of Tashlydere (Tashlyderin(skaya)) Fm. Fm. consists of gray thinly- medium-bedded micritic and slime limestones with chert concretions. At the leaning points of Ekerem(skaya) Fm. to huge reef buddings of Tashlydere Fm. from last aprons (“moustaches”) presented by clastic limestones thinning and disappearing as moving from the reef leave. At the places of overlaying of Ekerem(skaya) Fm. by more young Shakhliburun reef limestones are replaced by late diagenetic huge crystalline sugar-like white on fresh chip and black on weathered chip dolomites. Thickness of Fm. in areas where in totally coincides to Horizon is not more that 100 m. At the areas where Fm. replaces Tashlydere reef Fm. thickness abruptly changes from 0 above top of some reefs to 200 m within inter-reef spaces.

At the Upper part of Urumilidjan Gorge and in debris of right slope of Inzhirlydyi Gorge *Neocampylites* ex gr. *delmontanus* (Oppel), *Perisphinctes* (*Perisphinctes*) sp., *P. (Dichotomo- sphinctes)* cf. *dobrogensis* (Simionescu), *Liosphinctes* sp. indet. ex gr. *decipiens* (Sowerby), *Subdiscosphinctes* (*Subdiscosphinctes*) ex gr. *lucingae* (Favre), *Orthosphinctes* (*Pseudorthosphinctes*) sp. cf. *alternans* Enay, *O. (?P.)* sp., *O. ?* sp. juv., *Larcheria ?* sp., *Cardioceras* sp., *Eurasenia* cf. *trimera* (Oppel), *Peitoceratoides* (*Peitoceratoides*) aff. *indicus* Spath, *P. (Parawede-kindia)* ex gr. *arduennense* (d'Orbigny), *Euaspidoceras* sp. were found. From upper part of Fm. in Urumilidjan section *Chlamys inaequicostatus* Phill., *Rhactorhynchia corallina* Leym., *Dictyothyris roilieri* Haas are known. Microfauna includes: *Ammobaculites* sp., *Verneuilioides* sp., *Marssonella* ex gr. *doneziana* Dains *Spiroplectammina* sp., *Agathammina* sp., *Ophthalmidium stuifense* Paalzow, attached *Miliolidae*, *Nodosaria* sp., *Dentalina* sp., *Astacolus* sp., *Lenticulina* sp., *Ichtyolaria* (?) sp., *Spirillina* aff. *kubleri* Mjatl., *Epistomina uhligi* Mjatl. and also planktonic *Globuligerina oxfordiana* Grig., *Globochaete alpina* Lombard, *Cadosina fibrata* Nagy.

Fm. makes a clinotheme, maximum of thickness coincides to replacement zone of barrier reef by back-reef lagoon deposits and in space corresponds to maximal thickness of Djebel-Ata and Guzvash Fms.

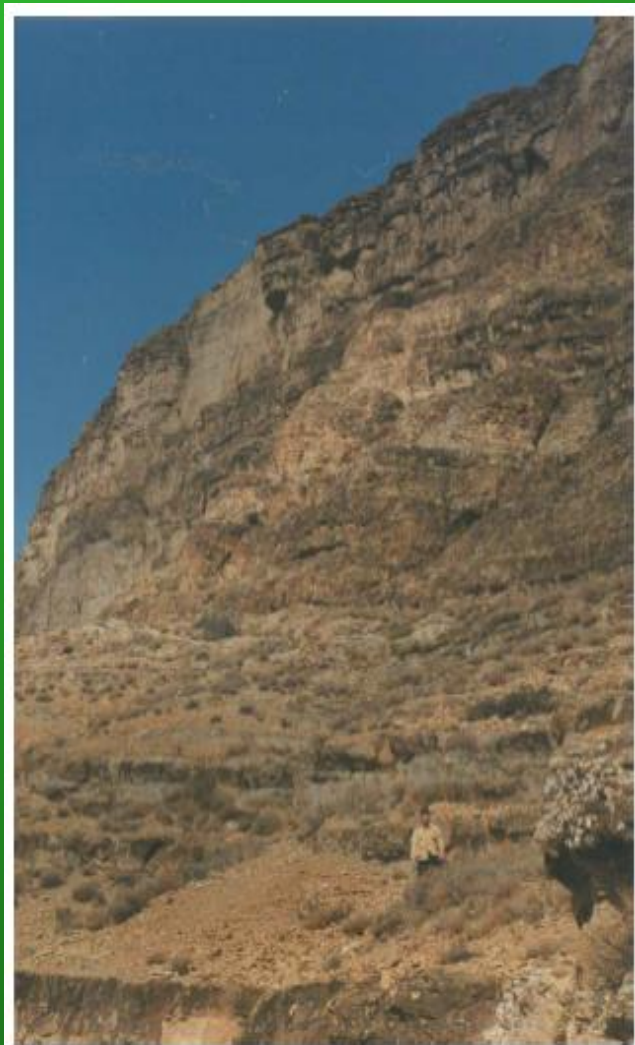


Figure AS3G. Rhythmically bedded Oxfordian limestones gradually pass into unit Oxfordian – Kimmeridgian massive dolomitized limestones and reef buildings. Goranki-Dere Gorge, Djebel'-Ata area, Great Balkhan. 20-25.01.1993. R.R.Gabdullin for the scale

Karaburun(skyi) Horizon (Kimmeridgian – Lower Berriasian)

Karaburun(skyi) Horizon was described by N.V.Beznosov and V.V.Kutuzova in 1985 and unites ***Soimonov(skaya), Dagdirim(skaya), Lyammaburun(skaya) Fms., Annanyaz(skaya), Inzhirs(skaya) units and Shakhliburun(skyi), Karaburun(skyi), North Monzhuklin(skyi) reef complexes*** laterally transiting into each other. Horizon represents deposits of complicatedly composited carbonate platform (Figs. AS3G–I)

Soimonov(skaya) Fm.

Soimonov(skaya) Fm. within Great Balkhan is exposed at Bordjokly Chain where dolomites of Ishekiol'(skaya) Fm. are covered by:

- 1.White sugar-like gypsum with subordinated beds of green clays. Thickness up to 15 m.
- 2.Red silty clays transiting into clayey horizontally bedded plated siltstones with subordinated beds of algael and micritic limestones. 6-7 m.
- 3.Lense-like alternated from pebble- to boulder badly sorted and rounded skew bedded conglomerates and sandstones. Channel incisions filled by conglomerates within more ancient rocks are observed. 30 m.

At the West and East of Bordjokly Chain Fm. is missing (is eroded) and than appears at the East of Kubadag (validation point no. 4). Absence of fossils is explained by continental environment.



Figure AS3I. Oxfordian – Kimmeridgian carbonate platform: lower and middle parts. Goranki-Dere Gorge, Djebel'-Ata area, Great Balkhan. 20- 25.01.1993. White tent for the scale

Lyammaburun(skaya) Fm.

Lyammaburun(skaya) Fm. is distributed within Oglanly Chain and also at Southern wing of Great Balkhan anticlinorium at Lyammaburun Ridge, Karaburun and Kazandzhiburun Mts. and at Eastern slope of Shakhliburun Ridge. At Oglanly Chain and Kyariz Mt. Lyammaburun(skaya) Fm. covers Ishekiol'(skaya) Fm. not distinctly separating by limestone unit (2,5-3 m) at the top of the last. Here Lyammaburun(skaya) Fm. is comprised by micritic and macro-crystalline medium-bedded dolomites with lenses of dolomitic breccias in the middle and upper parts of sequence. Thickness is up to 70 m. At the South Fm. fills the depression between Shakhliburun, Karaburun and North Monzhuklin reefs leaning to their slopes and totally disappearing – cutting out by Lower Cretaceous Arlan Fm. above reef top. Here Fm. unites medium- and thickly bedded dolomites and dolomitized limestones. Rock is microcrystalline with relicts of cloddy-clumpy and clastic textures. Rhythmically composition is presented by alternation of relatively hard and loose beds. Thickness of Fm. within depression between Shakhliburun & Karaburun and between Karaburun & North Monzhuklin reefs between reefs is 350 m. Fm. is characterized by big bivalves and gastropods collected at the Lower Tuezmergen Gorge: *Photadomya* ex gr. *gigantea* Sow., *Neitheia* ex gr. *simplex* Mordv., *Pterotrigonia* cf. *caudate* Ag., *Litschkovitrigonia*, *Corbis*, *Myopholas* spp., *Tylosioma*, *Upella* sp. Also Tithonian tinthinidae *Calpionella alpina* Lorentz occur.

Annanyaz(skaya) Unit is distributed within limited space of the Northern cliff of Great Balkhan between Dagdyrim and Ishekyol Mountain path (trail). Here with erosion above Ishekiol'(skaya) Fm are exposed:

1. Dolomitized light-gray partially with skew bedding stromatolite limestones with angular chert clasts. 2.5-3 m.
2. Light-gray massive partially with unclear skew bedding clastic oolitic limestones. 90-100 m.

Above with unconformity Arlan Fm. (Berriasian – Valanginian) lies. From oolitic limestone *Ammobaculites suprajurassicus* (Schw.), *Mesoendothyra* sp., *Alveoseptajaccardi* (Schw.) were determined.

Dagdirim(skaya) Fm. ***Dagdirim(skaya) Fm.*** is distributed within limited space between Upper Tuezmergen & Urumil'djan Gorges filling depressions in paleorelief between Annanyaz(skaya) Unit and Shakhliburun reef. Fm with erosion covers Ekerem(skaya) Fm.:

1. Gray algael stromatolite limestones with breccia of chert concretions at the base and within member. 5-6 m.
2. Black thickly- and medium bedded cloddy-clumpy partially clastic to different extent dolomitized limestones. Up to 120 m.
3. Gray thickly-bedded crystalline & dolomitized limestones with porphirite-like texture. 40 m.

At bed no. 2 ammonite *Ataxioceras* ? sp. , bivalves *Astarië quechenensis* Lor., *A. sauvagei* Lor., *Opis greppini* Lor. and also microfauna *Ammobaculites suprajurassicus* Schw., *Glamospirelia*, *Textularia*, *Trochammina*, *Verneuilinoides* spp., *Mesoendothyra izjumiana* Dam were met. At bed no. 3 *Quinqueloculina*, *Ophthalmidium* spp., *Guttulina* ? sp. appear.

Shakhliburun(skyi) reef

Shakhliburun(skyi) reef can be traced 18 km from SW submerging of Shakhliburun Ridge up to Upper Chukansu Gorge, it is 3–4 km wide.. It covers Ekerem(skaya) Fm. or reefs of Tashlydere barrier reef system. At the last case at the base of Shakhliburun(skyi) reef an erosion surface occur. Southern slope of reef is leaned by Lyammaburun(skaya) Fm. At the North one could see replacement of reef by bed no. 2 of Dagdirim(skaya) Fm. the most high beds of Dagdirim(skaya) Fm. leans the slope. Top of reef is with unconformity covered by Arlan Fm. Observing height of reef is 180-200 m.

Reef consists of white massive and biogermic-bedded detrital and biomorphic coral-algael limestones with units of inner reef lagoon cloddy-clumpy clastic thinly- and medium bedded limestone units of 8-10 m thick with cyanobyonts *Girvanella* sp. and others.

In reef limestones big *Pseudocyclammia lituus* (Yok.), *Alveosepta jaccardi* (Schr.), *Ammobaculites coprolithiformis sequanum* (Mohler), *A. suprajurassicus* (Schw.), *Reophax* sp., *Glomospirella* sp., *Mesoendothyra* sp., *Vernemlinoides* sp. were determined.

North Monzhuklin(skyi) reef

North Monzhuklin(skyi) reef is located to the South from Great Balkhan at the Eastern part of Kel'kor saline land. It is partially intersected by wells at the depth interval of 2190-2300 m. Reef is with unconformity covered by Arlan Fm. Reef is presented by chalk-like loose carbonates with remnants of colonial corals.

Shakhliburun reef is the most old, shifting to the South in the direction from the coast Karaburun and North Monzhukhlin reefs are younger.



Figure AS3I. Oxfordian – Kimmeridgian carbonate paltform: upper part. Goranki-Dere Gorge, Djebel'-Ata area, Great Balkhan. 20-25.01.1993.

Inzhirs(skaya) unit

Inzhirs(skaya) unit is distributed within Northern slope of Oglanly Chain and at Great Balkhan at the Upper Urumilidjan and Tuezmergen Gorges. It conformably covers Dagdirim(skaya) and Lyammaburun(skaya) Fms. and is mainly presented by carbonate gravelites usually replaced by dolomites. Thickness varies from 20 to 60 m. unit is with unconformity covered by limestones of Arlan Fm. Unit contains: *Glomospirella*, *Textularia*, *Ammobaculites*, *Gaudryina*, *Trochammina* spp., *Pseudocyclammina lituus* (Yok.), *Mesoendothyra* sp., *Trocholina* cf. *conica* Schlum., *Bolivinopsis*, *Conorboides*, *Siphotextulahella* (?), *Tiniinnopsola* sp. In the matrix skeletons of bivalves, gastropods, brachiopods, juvenile ammonites exist.



Figure AS4A. Locality scheme for field validation point. Pointer marks position one of innumerable outcrops accompanied by photos (see below).



Locality 4: Locality scheme for field validation point. Paleozoic volcanic rocks and Late Hercynian granites – core of Kubadag rise form in relief isometric hills surrounded by Turkmenbashi town. To the North a linear ridge of Mesozoic rocks is located.

Position (determined by Google Earth):

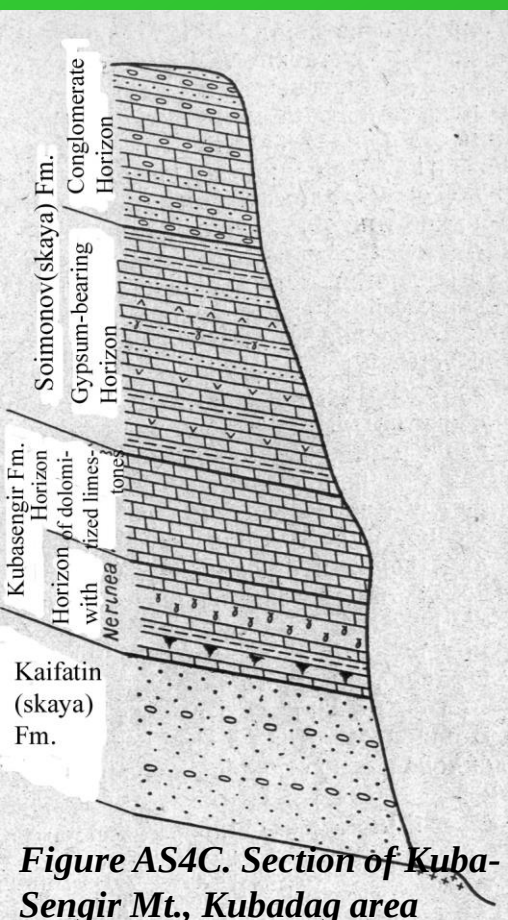
40.02.07.70 N, 52.55.28.45 E

Age: Callovian(?), Oxfordian–Tithonian

Sedimentology: Description
(Amanniyazov, 1971; Guide-book..., 1968) – Upper Jurassic deposits of Kubadag (Figs. AS4A–B) are strongly facially changing (in the distance of 2–3 km) along the Ridge
This circumstance and extremely rare fossils seriously complicated the study of the section. Lower boundary of Upper Jurassic deposits is not exposed, so type of contact and underlying rocks are still unknown. Only in on place at the Eastern ending of Turkmenbashi in a small exposure one could see strongly dislocated (folded) clayey shales and gravel conglomerates, transiting into conglomerate with pebble of a small size. Sandstones contain remnants of belemnites, bivalves and crinoids and possibly are analogs of Bathonian or Callovian deposits of Great Balkhan. The disappearance of Callovian deposits is caused by tectonic factor. The most ancient Jurassic rocks coinciding to massive sandy-conglomerate unit of Kaifatin(skaya) Fm.



Figure AS4B. A view to Kubadag ridge and Caspian Sea (Turkmenbashi – former Krasnovodsk, 27–28.01.1994, R.R.Gabdullin). Caspian Sea is transgressing: electric power line constructions (right) are partially drowned.



Oxfordian stage

Oxfordian Stage unites Kaifatin(skaya) Fm. and carbonate unit of Kubasengur(skaya) Fm.

Lower Substage(?), Kaifatin(skaya) Fm.

Rocks corresponding to Kaifatin(skaya) Fm. are exposed at 2 km to NW from railway station Kaylu and at 500 m to the North from railway. Formation is characterized by gray massive sandstones with thin beds of conglomerates and gravelites. Pebble of big and small size coincides to quartz, quartz porphyry, granite, diorite e t.c.

Railway station Kaylu section

Bed 1. Loose massive gravelly sandstone. 13.2 m.

Bed 2. Alternation of conglomerates and lenses of gravelite with medium-coarsed sandstone. 4 m.

Bed 3. Pink gravelly sandstone. 20 m.

Bed 4. Gray not hard gravelite. 1 m.

Bed 5. Sandy conglomerate with pebble of medium and small size. 3 m.

Bed 6. Light gray, nearly white not hard gravelite. 2 m.

Bed 7. Pinkish hard massive sandstone. 12.3 m.

Fossils are not observed, trace-fossils occur. Lower Oxfordian age is given due to overlaying paleontologically proved Upper Oxfordian rocks (Amanniyazov, 1971). General thickness of Fm. is 52 m.

Figure AS4C. Section of Kuba-Sengir Mt., Kubadag area (Amanniyazov, 1971).

Explanation is given in the text.

Upper Substage, Kubasengir(skaya) Fm.

To this Formation the carbonate part of upper Jurassic rocks of Kubadag is coincided. Rocks are exposed at Kaylu station and to the West from station Guesha extending in a stripe around Turkmenbashi from the Eastern and Northern-Eastern sides. Rocks are steeply inclined, sometimes overturned.

Rocks of Fm. are divided into 2 lithological horizons: 1) marly organogenous limestones; and 2) dolomitized limestones.

Railway station Kaylu section

Horizon of marly organogenous limestones (or *Nerinea* Horizon) – alternation of thinly bedded light gray organogenous limestones and marls with thin beds of clays and clayey argillites. Horizon contains gastropods and bivalves. At the lower part of Horizon shells of *Nerinea* sp. are usually met. At the upper part remnants of different bivalves are included into beds of cloddy (clumpy) marly limestones. Horizon can be spitted into 2 units: Lower of organogenous limestones and Upper of shaly dolomitized marls.

Lower (organogenous limestones) Unit is presented by slightly clayey cloddy limestones transiting in some places into the gastropod shell-rock with Late Oxfordian *Polyptyxis nodosa* Voltz. Kubadag is a unique place within whole Turkmenistan where big variety of innumerable gastropods is met. Unit is finished by conglomerate with pebble of the small size lying below the reddish-brown cloddy clays and clayey siltstones. Unit is 30.8 m thick.

Upper (shaly dolomitized marls) Unit is presented by light gray dolomitized and sandy, marly thinly bedded limestones. Unit is distinctly seen by the monotonous lithological style of dark brown section. At the lower half of the sequence limestones are fine- and coarse-grained, plate-like, thinly-bedded. At the upper half section limestones becomes sandy, strongly dolomitized with *Polyptyxis nodosa*. Thickness of the Member is 38 m. At the Soimonov Bay thickness is 45 m.

Horizon of dolomitized limestones can be easily seen by bench-like weathering profile:

Bed 1. Alternation of plate-like limestones with clayey-silty marls. 14.5 m.

Bed 2. Pelitomorphic thickly bedded limestone. 6 m.

Bed 3. Alternation of dolomitized sugar-like limestones with thin beds of marly dolomites. 14.5 m.

Here Horizon is 35 m thick, at the Soimonov Bay thickness is 72 m.

Kimmeridgian Stage

Soimonov(skaya) Fm. have 2 types of section: **Eastern (Kuba Sengir)**, **Western (Soimonov)**. Formation demonstrates strong facial variety.

Eastern (Kuba Sengir) type of section is characterized by 2 units: **Lower** – alternation of clayey and dolomitized siltstones and sometimes with sandy limestones with thin anhydrite beds and **Upper** conglomerate.

Western (Soimonov) type of section is presented by 2 units: **Lower** gypsum-bearing and **Upper** red colored sandy-silty rocks. An abrupt increase in thickness of gypsum-bearing and gypsum rock is observed to the West from Kok-Djol gypsum Gorge.

Soimonov(skaya) Fm. is divided into **Lower (Kimmeridgian)** and **Upper (conventionally referred to Tithonian) SubFm.**

Lower (Kimmeridgian) SubFm.

Railway station Kaylu section

Bed 1. Bedded clay. 1.2 m.

Bed 2. Alternation of silty limestones and white clayey sandstones. 15 m.

Bed 3. Alternation of quartz conglomerates with pebble of small size with thin beds of red clays and clayey siltstones. 5 m.

Bed 4. Light gray medium and coarse-grained sandstones. 1.1 m.

Bed 5. Alternation of clayey limestones with thin beds of anhydrite and silty clays. 7.5 m.

Bed 6. Slightly silty sandstones. 2 m.

Bed 7. Alternation of pelitomorphitic limestones and marls. 12.3 m.

Bed 8. Pelitomorphitic limestones. 4 m.

Bed 9. Carbonate medium-grained sandstone. 10 m.

To the West from Kaylu railway station rocks becomes more sandy and at the Kok-Djol first red gypsum-bearing siltstones occur. 2–3 km to the West an abrupt increase of thickness of chemogenous rocks is observed. it can be cause by tectonic factor. At the Soimonov bay a thickness of a single gypsum bed can increase up to 25 m. Here carbonate rocks are absent. Above the middle part of the SubFm. a horizon with small Kimmeridgian bivalves *Protocrdium dionisium* Buv., *Corbula carinata* Buv. is situated. General thickness of SubFm. is 76–145 m.

Tithonian (?) Stage

Upper SubFm. is presented by terrigenous unit.

Railway station Kaylu section

Bed 1. Alternation of differently coarsed sandstones, gravelites and conglomerates at the middle part. 13.2 m.

Bed 2. Carbonate coarse-grained sandstone. 40.5 m.

Bed 3. Carbonate sandstone. 48 m.

Bed 4. Carbonate conglomerate with pebble of a big size. 2.5 m.

Bed 5. Coarse-grained sandstone with thin beds of conglomerates. 15 m.

To the West from Kaylu station (Kok-Djol gypsum Gorge) thickness of conglomerate unit decreases. At the Soimonov bay area rocks of Upper SubFm. unite alternation of red, ash-gray clayey siltstones with light gray, gray sandstones gradually submerging below Lower Cretaceous limestones.

Lower Soimonov SubFm. is an analog of Gaurdak Fm., Upper Soimonov Fm. – analog of Karabil' Fm. of Gaurdak–Kugitang area (field validation points no. 6–13).

Interpretation - Shallow-marine, lagoon environment.

Structure: Kubadag Ridge extends along the Northern bank of Turkmenbashi (former Krasnovodsk) Bay (Fig. AS4B) and represents the Northern wing of anticline (Fig. AS4A). Nucleus is comprised by igneous Paleozoic rocks (Fig. AS4D) which are over-thrusted upon the sedimentary Mesozoic deposits at the West. At the East – Mesozoic rock transgressively covers Paleozoic one. Ridge has an asymmetrical shape: Southern slope is represented by a steep cliff, Northern – by a weakly hilled plateau-like surface. Southern slope consist of Upper Jurassic and Lower Cretaceous deposits that are steeply inclined and even overturned at the North. Deposits are intersected by innumerable transversal up-faults of small amplitude. Eastern part of Ridge is lesser tectonically disturbed, rocks has northern inclination with angles of 10–20° (Guide-book..., 1968).

Regional significance: This validation point is located within the Kubadag

Petroleum systems information: No data



Figure AS4D. A view from exposures of Paleozoic volcanic rocks and Late Hercynian granites (core of Kubadag rise) to Caspian Sea and Turkmenbashi (27 – 28.01.1994, R.R.Gabdullin).



Field trip. Validation points

ASIA 5



Figure AS5A. Locality scheme for field validation point.

Locality 5: Kopetdag ridge, Koy-Ata Cave, Ahal welayaty, Central Turkmenistan, near Iran border

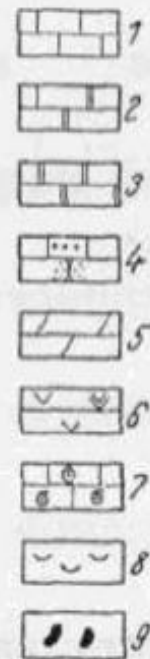
Position (determined by Google Earth): 38.21.09.09 N, 57.23.28.26 E

Age: Oxfordian–Tithonian

Figure AS5B. The entrance into the cave. Arrow shows one of natural entrances – wells. 26 – 27.01.1993

Sedimentology: Description
(Amanniyazov, 1971) –
Oxfordian–Tithonian sequence of Central Kopetdag can be observed near the famous Bakharden Koy-Ata cave with underground hydrothermal lake (Figs.AS5A–C). Sections are distributed near Kel'ata railway station and in the vicinity of a cave.

Oxfordian		Oxf.-Kimm.	Age	
Lower(?)	Upper		Kim.-Tithon.	Low. Cret.
			Lithology	
Garadzhagain(skaya)	Mekhin-suss(kaya)	Uzynsyr(skaya)	Ellyderyn-(skaya)	Formation
32-169	210-270	240-270	142-157	Thickness, m
Lower Oxford.	Upper Oxfordian	Kimmeridgian	Tithonian	Stage
I	II III IV	V	VI VII VIII	Member.
709	2420-100	124-172	161-206	Thickness, m
Lower Oxford.	Upper Oxfordian		Kimmeridgian-Tithonian	Stage



Oxfordian Stage

Lower substage

Garadzhagain(skaya) Fm. is exposed near **Kel'ata** railway station. Upper part of Fm. can be seen near the cave. Fm. mainly unites Dark gray dolomitized limestones and dolomites. Fm. consists of massive and hard rock. Fm. can be divided into 2 horizons: Lower and Upper.

Lower or Dolomite Horizon (123,5 m) is presented by a thick dolomite unit.

Section in the vicinity of Kel'ata station

Bed 1. Dolomitized thickly bedded limestone. 16 m.

Bed 2. Gray thinly bedded dolomite. 6 m.

Bed 3. Medium-grained carbonate dolomite. 0.55 m.

Bed 4. Alternation of fine- and silt-grained limestone with gray sandy bedded dolomite. 18 m.

Bed 5. Carbonate massively bedded dolomite. 31 m.

Bed 6. Dark gray carbonate dolomite. 18 m.

Bed 7. Alternation of carbonate dolomite with coarse- and medium-grained dolomite. 8 m.

Bed 8. Fine-grained dolomite. 5.1 m.

Bed 9. Dark-cherry colored fine- and coarse-grained dolomite. 20 m.

Figure AS5C. General section of Upper Jurassic deposits at Kov-Ata cave (Central Kopet-Dag)(GEOLOGY OF USSR, 1972): 1 – limestone; 2 – dolomitezed limestone; 3 – dolomite; 4 – silty-sandy limestone; 5 – marl; 6 –gypsum, anhydrite; 7 – organogenous-clastic limestone; 8 – detrite; 9 – chert concretions, insertions.

Upper or Dolomitized Limestone Horizon (45 m) is presented mainly by dark gray fine-grained dolomitized limestones with chert concretions. it differs from the Lower Horizon by appearance of chert concretions.

The exposed part of Fm. near the cave is 32 m, in Kel'ata area – 168.5 m. fm. is lying under paleontologically characterized Upper Oxfordian rocks, so age of Fm. is conventionally considered to be Lower Oxfordian.

Upper Substage

Mekhinsuss(skaya) Fm. is presented by thick unit of alternation of dark gray thinly bedded clayey limestones with dark gray organogenous, organogenous-clastic and cloddy limestones. At the top of Fm. a unit of thick bedded limestones with chert concretions, sponges and single corals. *After hammering a strong smell of H₂S one can feel.* Formation was named by Mekni-Su spring, located 1 km to the West from exposure of rocks of mentioned Fm. Formation can be divided into 2 Horizons: *Lower of clayey limestones and Upper – of thick bedded limestones with chert concretions.*

Lower Horizon of sheet-bedded clayey bituminous limestones are well exposed at Koy-Ata area at the cupola part of anticline at Indzhreva River valley. Here this part of Fm. is presented by alternation of sheet-bedded clayey bituminous limestones with organogenous limestones.

- Bed 1. Thin bedded clayey limestone. 1.7 m.
- Bed 2. Dark gray hard limestone. 2.7 m.
- Bed 3. Greenish-gray cloddy clayey marl. 3.5 m.
- Bed 4. Dark gray organogenous-clastic limestone 2.3 m.
- Bed 5. Clayey sheet-bedded limestone. 2.8 m.
- Bed 6. Organogenous-clastic limestone. 1 m.
- Bed 7. Analog of bed no. 5. 1.2 m.

Bed 8. Gray organogenous-clastic limestone. 1.6 m.

Bed 9. Analog of bed no. 5. 9.5 m.

Bed 10. Dark gray organogenous-clastic limestone. 10.7 m.

Bed 11. Analog of bed no. 5. 17 m.

Bed 12. Analog of bed no. 6. 3 m.

Bed 13. Analog of bed no. 5. 12 m.

Bed 14. Analog of bed no. 6. 17 m.

Bed 15. Analog of bed no. 5. 27.5 m.

Bed 16. Fine-grained dark gray hard partially organogenous limestone. 2.7 m.

Bed 17. Dark gray thinly-, sheet-bedded limestone. 4.7 m.

Bed 18. Analog of bed no. 6. 14.5 m.

Bed 19. Alteration of sheet-bedded dark gray clayey limestones with organogenous-clastic limestones. 12.6 m.

Bed 20. Dark gray oolite limestone. 3.6 m.

Bed 21. Analog of bed no. 5. 20 m.

Bed 22. Organogenous-clastic Dark gray bedded limestone. 1.2 m.

Bed 23. Analog of bed no. 5, but also thinly-bedded. 4.1 m.

Bed 24. Organogenous-clastic cloddy limestone. 10.4 m.

Bed 25. Analog of bed no. 5. 23.5 m.

Thickness of Horizon is 210.8 m. At Koy-Ata area this interval of section is 160.5 m thick.

From lower part of this Horizon from Kel'-Ata area *Perisphinctes biplex* Sow., *P. plicatilis* Sow., *P. elisabethae* Riaz, *P. aeneans* Gemm., *P. ex. gr. orbigny* Loriol, *P. lucingensis* Favre, *P. sp. indet.*, *Calliphylloceras* sp. are known. These fossils mostly characterize Upper Oxfordian. From this interval bivalves *Parallelodon* aff. *oemulum* Phill., *Gervillia* ex gr. *aviculoides* Sow., *Isognomon* cf. *paramytiloides* Arkell, *Ctenostreon* cf. *proboscideum* Sow., *Modiolus* cf. *aequiplicata* Strom., *Mytilus* aff. *jurensis* Merian, *Goniomya* aff. *kobyi* Lor., *Astarte* sp. indet., *Trigonia* (*Myophorella*) sp. indet., *Protocardia* sp. indet., *Entolium* sp., *Pleuromya* sp. were found. Brachiopods *Ptyctothyris* ex gr. *andelotensis* Hass, *P. aff. karabugaensis* Moiss. are met. At Koy-Ata cave Upper Oxfordian ammonites *Perisphinctes biplex* Sow., *P. plicatilis* Sow., *Lytoceras* sp. indet. at the base of Fm. were found.

Upper Horizon of thick bedded limestones with chert concretions.

Bed 1. Dark gray organogenous-clastic limestone. 15.1 m.

Bed 2. Dark gray fine-grained limestone. 11.9 m.

Bed 3. Fine-grained thickly-bedded limestone. 2.8 m.

Bed 4. Fine-grained thinly-bedded limestone. 3.2 m.

Bed 5. Fine-grained thickly-bedded limestone with chert concretions at the top. 3.8 m.

Bed 6. Analog of bed no. 2. 10.9 m.

Thickness of Horizon is 47.7 m. At Koy-Ata area this interval of section is 160.5 m thick.

Kimmeridgian Stage

Uzynsyrt(skaya) Fm.

At Kel'-Ata station this Fm. is presented by thinly- and thickly-bedded gray or brown micro-grained and crypto-grained limestones. Lower part of Fm. is presented by unit of mainly thinly-bedded dark gray fine-grained limestones. Upper part consists of alternation of massive and thinly-bedded limestones. Fm. is ended by unit of clayey rocks. Thus, 3 horizons are established. At Kel'-Ata area rocks of Fm. form a steep cliff of the same-named ridge.

Horizon of alternation of thickly- and thinly bedded limestones with fine-grained dark-gray hard and thinly bedded limestones.

Bed 1. Dark gray pelitomorphic thickly bedded limestone. 4 m.

Bed 2. Dark gray clayey thinly-bedded limestone. 7 m.

Bed 3. Slightly sandy limestone. 1 m.

Bed 4. Greenish-gray cloddy marl. 4 m.

Bed 5. Gray clayey thickly bedded limestone. 9 m.

Bed 6. Light gray sandy marl. 1 m.

Bed 7. Dark gray pelitomorphic limestone. 4 m.

Bed 8. Dark gray clayey organogenous limestone. 8 m.

Bed 9. Dark gray pelitomorphic thickly bedded limestone. 26 m.

Bed 10. Alternation of marls, limestones and clays. 8 m.

Bed 11. Light gray hard clayey marl 3 m.

Bed 12. Dark gray pelitomorphic cloddy limestone. 2 m.

Bed 13. Organogenous limestone. 3 m.

Bed 14. Alternation of thickly bedded limestones with cloddy thinly bedded limestones. 25 m.

Bed 15. Thickly bedded pelitomorphic limestone. 10 m.

Bed 16. Light gray dolomitized marl. 1 m.

Bed 17. Gray pelitomorphic limestone. 2 m.

Total thickness of Horizon is 124 m.

At the base, middle and upper part of described Horizon beds rich in bivalves, brachiopods, gastropods exist. Ammonites are rare. From this Horizon bivalves *Chlamys* cf. *vininea* Sow., *Arcomytilus* aff. *morriisi* Sharpe, brachiopods: *Iuralina repelliniana* Orb., *I. bullingdonensis* Roll., *Lobothyris valfinensis* Lor., *Postepithyris bauhini* Et., *P. etalloni* Roll., *P. aff. tipica* Kjansep, *Rhactorhynchia pinguis* Roem., *R. corallina* Leym., *Lacunosella trilobataeformis* var. *ventriplana* Wisn. are known.

Clayey Horizon consists of alternation of carbonate clays and clayey-silty limestones.

Bed 1. Alternation of light gray marl with sandy clay. 6 m.

Bed 2. Green carbonate hard clay. 5 m.

Bed 3. Light gray hard marl. 1 m.

Bed 4. Alternation of clays, sandstones and marl. 7 m.

Bed 5. Light gray clayey bedded limestone. 8 m.

Bed 6. Limestone with thin clay beds. 6 m.

Bed 7. Limestone with thin clayey limestone beds. 12 m.

Total thickness of Horizon is 45 m.

At Koy-ata cave area this Fm. is presented by alternation of gypsum-anhydrite rocks with dark organogenous limestones. Relatively more weak rocks are presented by clayey siltstones, anhydrites, gypsum, gypsum-bearing sandstones. White grained gypsum is loose at the surface. Kimmeridgian age of Fm. is based upon mentioned fossils.

Tithonian Stage

Y(e)llyderyn(skaya) Fm. was named by the same-named gorge located just to the West from Koy-Ata cave. These rocks form a steep ridge inside which a cave is located (Figs. AS5D–F). Here a section is presented by massive limestones with rare lenses of anhydrite. At Kel'-Ata station Upper Jurassic sequence is finished by light gray massive fissured limestones. Dark gray dolomitized limestones with anhydrite lenses can be observed near Ashgabat at Firusa Gorge.

Below description of section near Kel'-Ata station is given.



Figure AS5D. Exposure of rhythmically bedded rocks of Y(e)llyderyn(skaya) Fm. View from West to East near the entrance into the cave. 26–27.01.1993



Figure AS5E. Exposure of rhythmically bedded rocks of Y(e)llyderyn(skaya) Fm. View from South-West to North-East. Entrance into the cave is situated at the left. White tent at the right – for a scale. 29–30.01.1994

Bed 1. Dark gray fine-grained bedded limestone. 10 m.

Bed 2. Dark gray fine-grained thinly- and thickly bedded limestone. 21.3 m.

Bed 3. Dark gray fine-grained thinly bedded limestone. 2.6 m.

Bed 4. Analog of bed no. 1. 16.1 m.

Bed 5. Dark gray fine-grained thickly bedded limestone. 2 m.

Bed 6. Clayey thinly bedded limestone. 1.8 m.

Bed 7. Dark gray hard bedded limestone. 24.8 m.

Bed 8. Dark gray limestone with thin beds of marly dolomite. 9.2 m.

Bed 9. Clayey fine-grained limestone. 14.3 m.

Bed 10. Alternation of thinly bedded light gray marly-dolomitized limestones with fine-grained limestones. 27.8 m.

Bed 11. Gray thickly bedded limestone. 32 m.

Bed 12. Gray massive fine-grained limestone. 15 m.

Bed 13. Re-crystallized massively bedded limestone. 12 m.

Bed 14. Gray thickly bedded massive limestone. 12 m.

In the vicinity of this validation point Turkmenistan–Iran border is located. From the top of Ridge comprising the cave geology and geomorphology of core of anticline can be seen (Figs. AS5G–H)

Interpretation - Shallow-marine environment.

Structure: At Koy-Ata area, 800 m from the beginning of Indjereva River in the core of the fold upper beds of Garadjagain(skaya) Fm. are strongly dislocated.

Regional significance: This validation point is located within the Kopet-Dag

Petroleum systems information is given at §6



Figure AS5G. A View from the Ridge comprising Koy-Ata Cave.

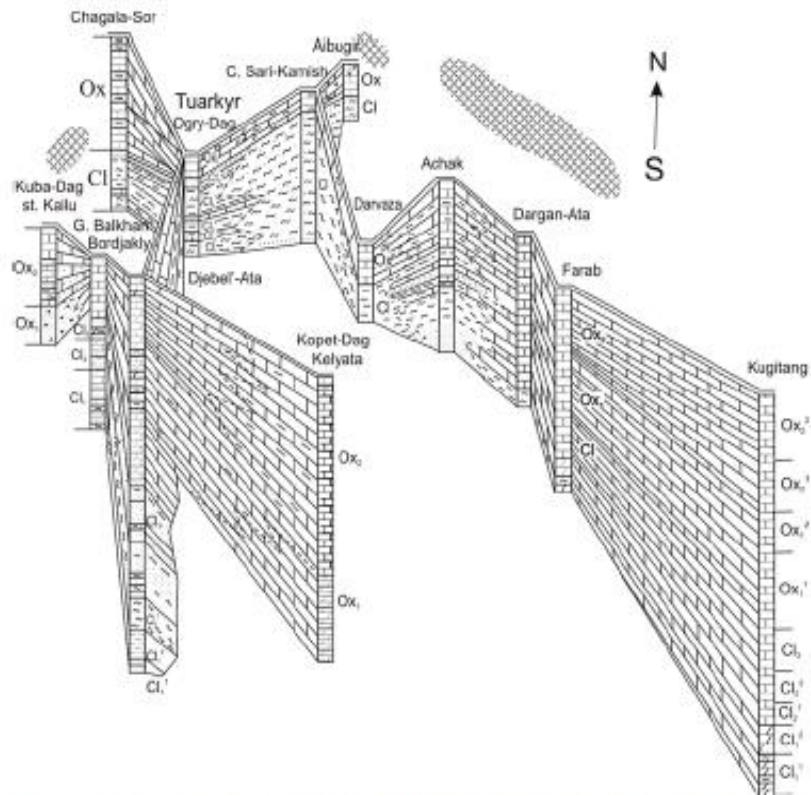


Figure 4.1. Three dimensional facial profile of Callovian–Oxfordian deposits of Turkmenia (Amanniyazov, 1971). By cross shading denudation areas are shown.

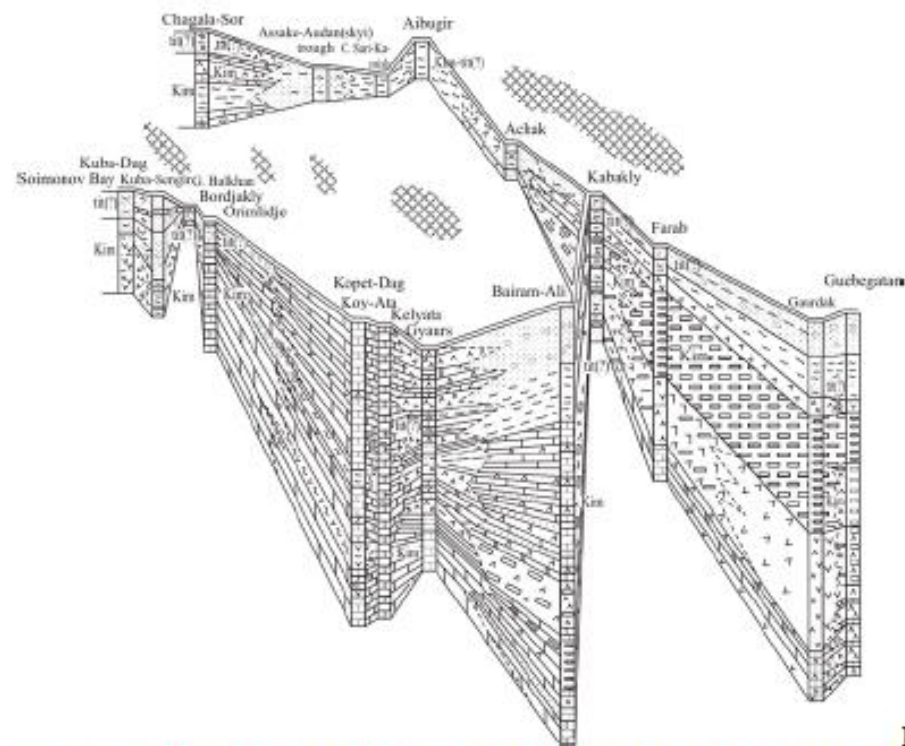


Figure 4.2. Three dimensional facial profile of Kimmeridgian–Tithonian deposits of Turkmenia (Amanniyazov, 1971)

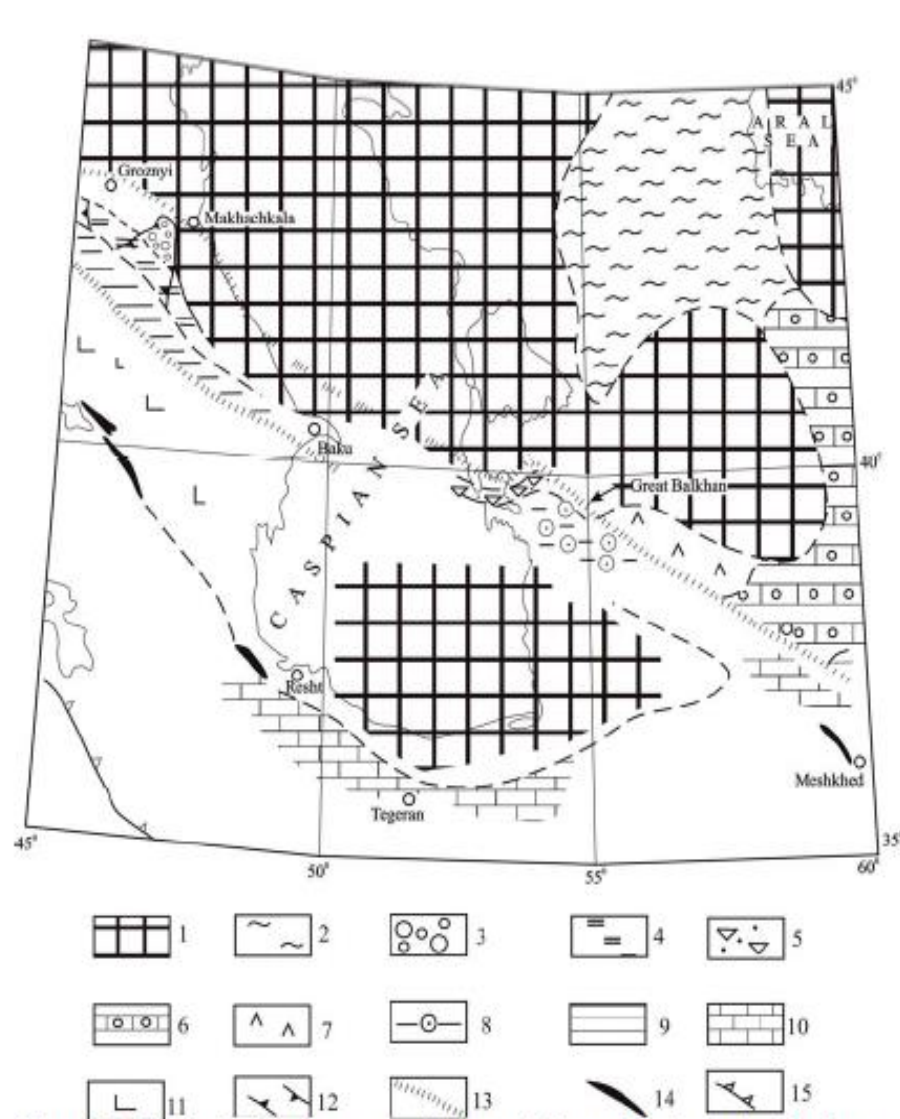


Figure 5.1. Lithological – paleogeographic map of Circum-Caspian region for Late Bathonian–hervei time of Early Callovian (Beznosov, Mitta, 2000): 1 – areas of erosion; 2 – lake-swamp lowland; 3 – alluvial filling of paleovalleys; 4 – coastal lowland at Late Bathonian transiting into shelf one at the Early Callovian; 5 – divided coast; 6 – shallow shelf and tidal plain periodically alternating each other; 7 – weakly salted lagoon; 8 – shallow shelf; 9 – trough, flysh trough, prodelta; 10 – basin with carbonate sedimentation; 11 – arc area with strongly divided relief; 12 – areas of distribution of late Bathonian deposits within Northern slope of Caucasus; 13 – suture zones limiting Turan Plate and miogeosynclinal of Great Caucasus; 14 – exposures of ophiolites and coloured melange along the Northern side of Iranian plate; 15 – Zagros suture.

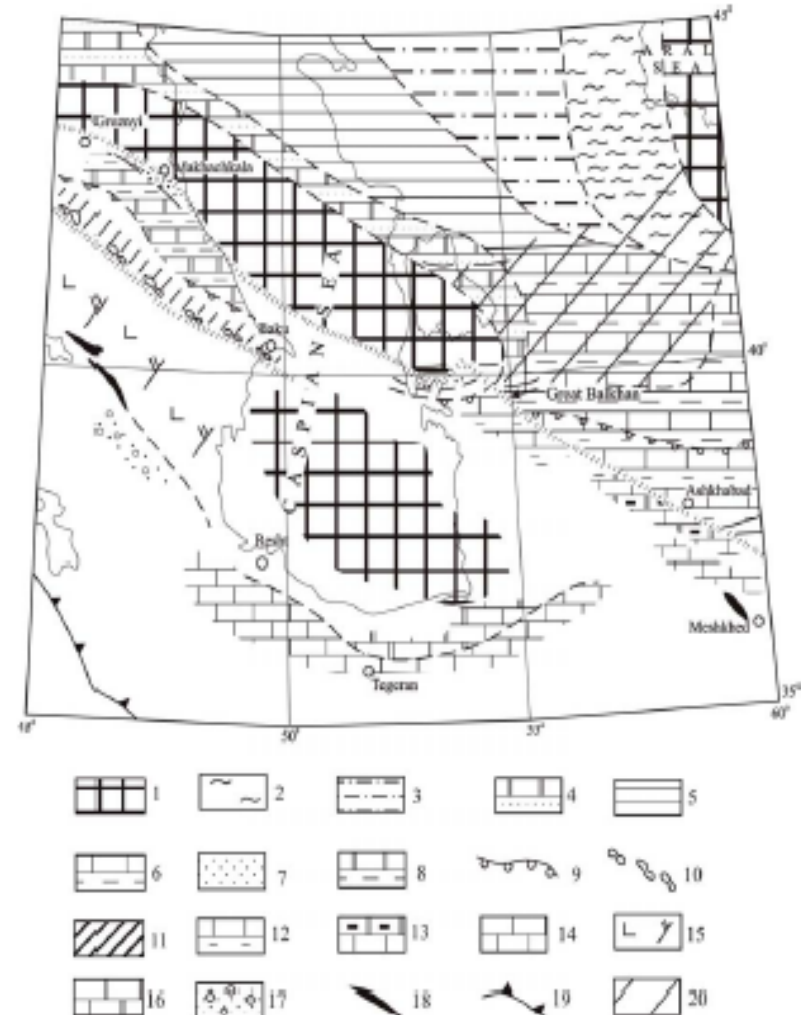


Figure 5.2. Lithological – paleogeographic map of Circum-Caspian region for Callovian (except hervei time) and Oxfordian (Beznosov, Mitta, 2000): 1 – areas of erosion; 2 – coastal above-tidal plains; 3, 4 – tidal planes–shallow shelf: 3 – with terrigenous sedimentation, 4 – with terrigenous and carbonate sedimentation; 5 – differentiated by depth carbonate basin; 6 – open shelf with terrigenous sedimentation in Callovian transiting into carbonate one at the end of Callovian and in Oxfordian; 7 – littoral with sandstone and sandy dolomite accumulation; 8 – back-reef lagoons and tidal plains; 9 – outer fronts of barrier-reef systems; 10 – olistolite belt of reef limestones within thrust zone of Southern slope of Caucasus; 11 – flysh trough; 12 – basin with clayey and carbonate sedimentation; 13 – basin coming into the trough with accumulation of sapropel dolomites; 14 – basin coming into (shallow) shelf; 15 – arcs with island reefs; 16 – “littoral” with carbonate sedimentation; 17 – coastal quartz sands and conglomerates; 19 – Zagros suture; 20 – area of uplift and erosion of Turkmenian anticline occurred since Middle of Oxfordian.

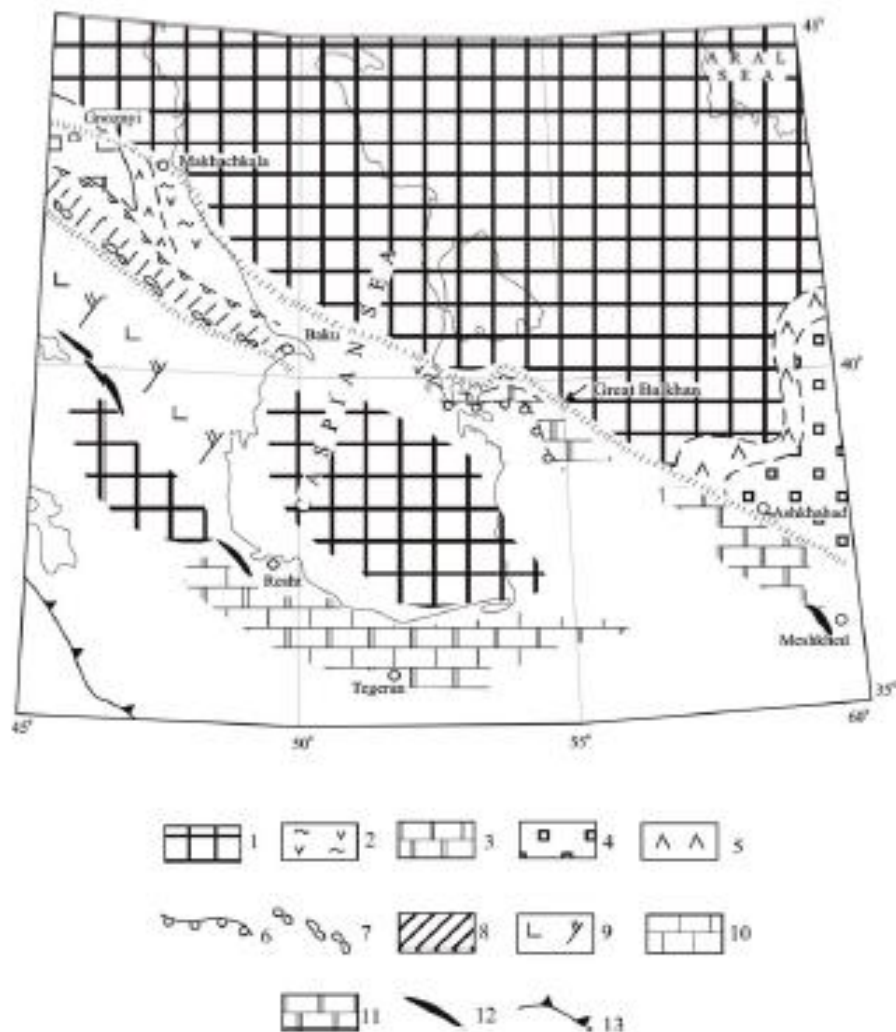


Figure 5.3. Lithological – paleogeographic map of Circum-Caspian region for Early Kimmeridgian (Beznosov, Mitta, 2000): 1 – areas of erosion; 2 – coastal above-tidal plains with accumulation of lake and proluvial deposits; 3 – tidal planes, lagoons; 4 – basins of salt accumulation; 5 – zone of the maximal freshening of salted water; 6 – outer fronts of barrier-reef systems; 7 – olistolite belt of reef limestones within thrust zone of Southern slope of Caucasus; 8 – flysh trough; 9 – arcs with island reefs; 10 – shelf with carbonate sedimentation; 11 – shelf-tidal plane (?); 12 – exposures of ophiolites and coloured melange along the Northern side of Iranian plate; 13 – Zagros suture.

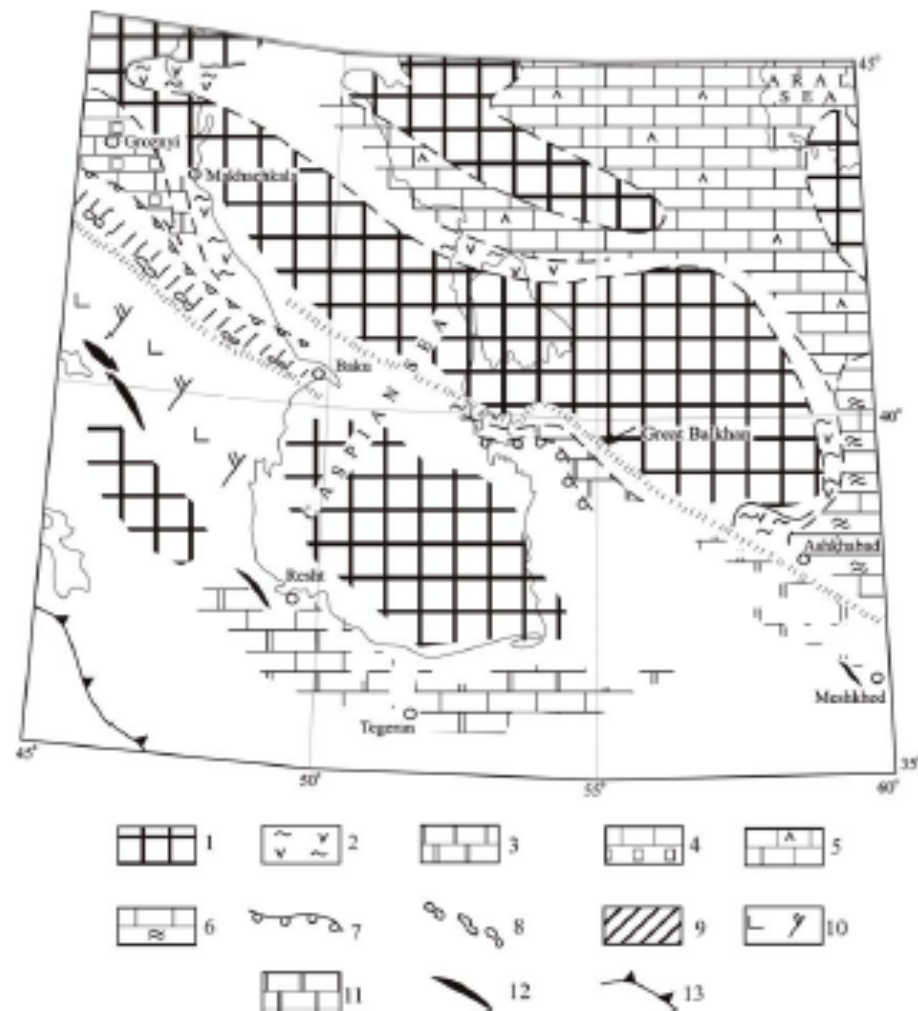


Figure 5.4. Lithological – paleogeographic map of Circum-Caspian region for Late Kimmeridgian – Tithonian (Beznosov, Mitta, 2000): 1 – areas of erosion; 2 – coastal above-tidal plains with accumulation of lake and proluvial deposits; 3 – lagoons-tidal planes, coastal lowlands; 4 – basins of salt accumulation transformed in Middle – Late Tithonian by shallow shelf; 5 – shallow cratonic basin, inwashed bars, lagoons; 6 – the same as 5, but transformed in the end of Tithonian by salty lagoon transiting into alluvial plain; 7 – outer fronts of barrier-reef systems; 8 – olistolite belt of reef limestones within thrust zone of Southern slope of Caucasus; 9 – flysh trough; 10 – arcs with island reefs; 11 – shallow shelf, "littoral" (?); 12 – exposures of ophiolites and coloured melange along the Northern side of Iranian plate; 13 – Zagros suture.



Figure 2.2.9. Geological map (Geology of USSR, 1972) of Eastern Turkmenistan with position of field validation point no. 6, 7, 9, 10 within Kugitang-Baisun folded zone.



Figure 2.2.10. Geological map of Western Uzbekistan with position of field validation point no. 8, 11, 12, 13 within Kugitang-Baisun folded zone.



Sedimentology: – Description (Beznosov, Mitta, 1995)
– At the Southern part of Gaurgak Mt to the South from the latitude of Shurcha spring the following sequence is exposed (Figs AS6A – B):

Kugitang Super Formation. J₃O₂

1. Shurcha reef massif.

1.1. Nucleus of reef. White massive and biogerm-bedded, corallitic, algael, bioclastic limestones. Weakly porous kinds of rock are filled by oxidized bitumen (“anthraxolite”) and have black color. Colonies of reef building organisms are deposited in situ and in overturned position inside matrix of bioclastic limestones with abundant rudist and gastropod shells. Massive and biogerm-bedded limestones contain lenses (up 5–6 m) of plate-like litho-bioclastic limestones below level of carbonate gravelites. Foot of reef is not exposed, top is irregular, make addendums of 25–30 m high. Upper of addendums often is comprised by algael limestones. Reef is maximally exposed at gullies of the SE slope, come down to the Shurcha spring up to 100 m of visual

thickness. Separate exposures of reef top can be seen in the cupola of Gaurdak anticline at the area of the top, and in gullies, come down from this top to the cemetery at the Eastern ending of Gaurdak village and to the Agudash spring. From biogerm limestones following foraminifers were determined: *Earlandia* (?) sp., *Ammobaculites* ex gr. *coprolitiformis* (Schwag.), *Everticyclammina* (?) sp., *Nautiloculina* sp., *Labyrinthina mirabilis* Wench., *Gaudryina* spp., “*Valvulina*” aff. *langeoni* Septfontaine, *Belorussiella* sp., *Quinqueloculina semisphaeroidalis* Danitch.



Figure AS6A. Locality scheme for field validation points no. 6 and 7. Gaurdak anticline is seen from the space.

Locality 6: SE slope of Gaurdak ridge, Lebap welayty, Eastern Turkmenistan

Position (determined by Google Earth): 37.49.55.41 N, 66.07.15.47 E

Age: Middle Oxfordian – Lower Kimmeridgian

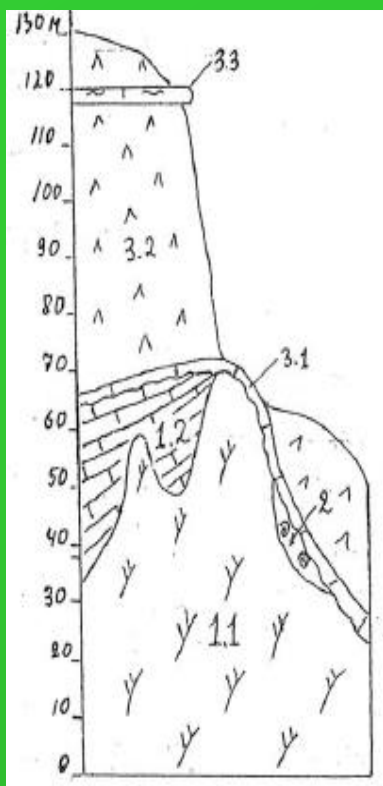


Figure AS6B
(Beznosov, Mitta, 1995). Sequence of terminal part of Kugitang Super Fm. and basal part of Gaurdak Super Fm. in the vicinity of Shurcha spring and to the South from it.

1.2. Facies of inner-reef lagoons and inwash (aggradational) bank (bar). Filling the depressions of relief of reef and leaning to addendums of biogerm limestones mainly medium-bedded gray to black (because of saturation in anthraxolite) presented by lithoclastic (up to conglomerates), cloddy (clumpy)–clotty, pellet kinds. A single coral biogerm up to 3–5 m high and first meters in diameter and thin beds of rudist limestones occur. In calcarenites a rich forameniferal assemblage is found: *Mesoendothyra izumiana*, Dain, *Pseudocyciammina* cf. *sphaeroidalis* Hottinger, *P. lituus* (Jok.), *Alveosepta* cf. *powersi* (Redmond), *Amijiella amiji* (Henson). Inside clumpy–clotty and pellet limestones following list of foraminifers is detected: *Glomospira*, *Earlandia* spp. indet., *Ammobaculites* cf. *suprajurassicum* (Schwag.), *Agathammina* cf. *antiqua* Said et Barakat. Thickness of plate-like limestones is seriously changing in dependence of relief of underlying biogerm limestones from 0 m above addendums up to 50–60 m (visual thickness) within SE part of Gaurgak anticline.

J_{3o3} 2. On NE reef slope, filling depressions of relief, at the left branch of gully coming down to Surcha spring a lenses of ammonite shell rocks of 1 m thick are met. Small shells of *Divisosphinctes bifurcatus* (Quenstedt), *D.ex gr. bifurcatus* (Quenstedt) dominates among others.

Gaurdak Super Formation. J_{3km1}

3. Analogs of Lower Anhydrite Fm., Lower Salt and Middle Anhydrite Fm., Lower Part. 3.1. Dark-gray limestones irregularly medium-bedded, lithoclastic with pebble of limestones at the base, at the top fine-grained with crack (opening)-like pores occur. Thickness 0,2–1,5 m.

3.2. White sugar-like massive gypsum loose (at the surface) on depth of 2–3 m transiting into anhydrites is 60-70 m thick.

At the lower part of anhydrite (gypsum) tomour-like impurities and lensic beds of black limestones with hollowings (“nests”) and small veins of virgin sulfur and also gatherings of black loose calcite-gypsum mass with sulfur crystals are observed. These sulfur-bearing limestones sometimes interpreting as black shales are epigenetic and occur because of sulfate-reduction reactions during disintegration of carbon-hydrogene deposits in Shurcha reef.

3.3. Gray irregularly thin- and medium-bedded, fine-grained sometimes thin-striped "stromatolite" limestones. Limestone bed is used as a marker horizon within Gaurdak deposit of virgin sulfur (bed Rt). Thickness is 3–4 m. Gypsum with limestone bed Rj are lying above. Complete thickness of Kugitang Super Formation in the vicinity of Gaurdak settlement according to drilling data is 568 m. Thickness of Gaurdak Fm. is 750–850 m.

Interpretation - Shallow-marine, lagoon environment.

Structure: No data

Regional significance: This validation point is located within Gaurdak anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data

Description ((Beznosov, Mitta, 1995) – North of Gaurdak Mts. and Tubegatang Mts.

To the North from Shurcha spring at the rise of joint (swivel) of Gaurdak anticline along the bed R1 because of the abrupt increase of thickness of anhydrite unit (bed 3.2) a top of Kugitang Super Fm. submerges below gypsum and then again is exposed 3-4 km to the North at the Beshbulak gully. From this place it discontinuous exposures can be traced at E-SE wing of anticline up to N-NE periclinal of this fold. The following section can be observed (Fig. AS7A):

Kugitang Super Fm. J₃O₂

1. Zakharlin(skaya) Fm.

1.1. Black mainly thin-bedded micritic limestones with ammonites *Otosphinctes* sp., *Perisphinctes* ex gr. *martelli* (Oppel), *P.spp.* indet. Undeterminable lenticulins (foraminifers) in association with *Globochaeta alpina* Lombard, *Quenqueloculina* sp., *Nodosaria* sp., *Astacolus* sp. and making great gatherings in separate beds *Epistomina uhligi* Mjatl. are met. Visual thickness is up to 40–50 m.

1.2. Black medium-bedded micritic limestones with *Kranaosphinctes* (*Kranaosphinctes*) sp. ex gr. "aff. *subcolubrinus*" (Spath), *Perisphinctes* (*Perisphinctes*) spp., *Gregoryceras tenuisculptum* Gygi. Thickness is 0,7–1,5 m.

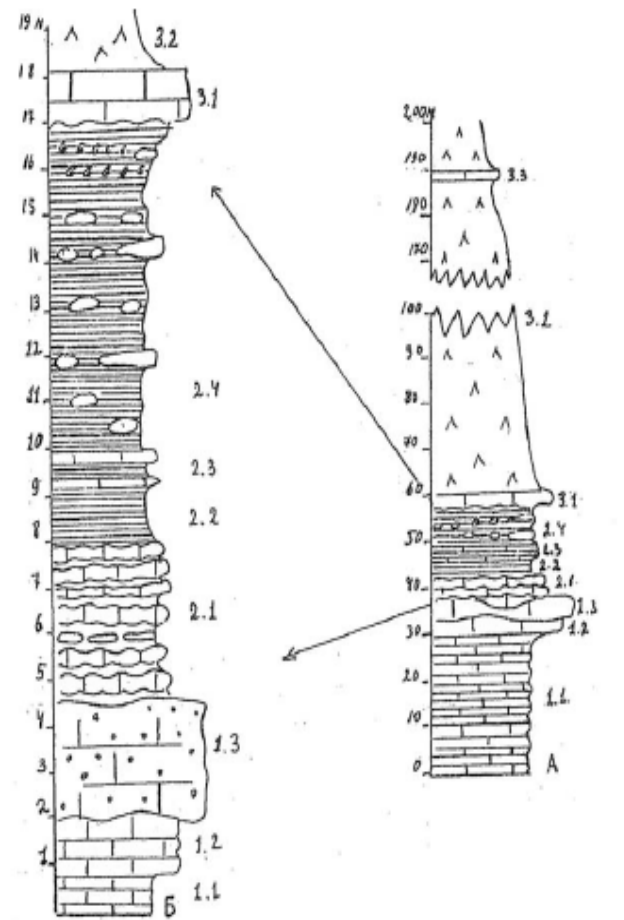


Figure AS7A (Beznosov, Mitta, 1995). Sequence of Kugitang and Gaurdak Super Fm.: A – complete section; B – section of Gudzhumtubegatang(skaya) Fm. in enlarged scale.

Locality 7: Shurcha spring
(Beshbulak Gully), Lebap welayty,
Eastern Turkmenistan

Position (determined by Google
Earth): 37.50.59.14 N, 66.09.00.04 E

Age: Middle Oxfordian -
Kimmeridgian



1.3. Gray litho-bioclastic limestones partially transiting into carbonate gravelite with bivalve and brachiopod shells and boulders of coral limestones are exposed in a lensic bed of 3 m thick totally disappearing to the North. List of foraminifers includes: *Mesoendothyra izumiana* Dain, *Pseudocyclamina ci. sphaeroidalis* Hottinger, *P. lituus* (Jok), *Alveosepta cf. powersi* (Redmond).

J₃O₃–?km₁

2. Gudzhumtubegatang(skaya) Fm.

2.1. Gray node-bedded fine-grained slime exfoliated by black clayey-bituminous mass limestones with ammonites *Kranaosphinctes* (*Kranaosphinctes*) sp., *Dichotomosphinctes efimovae* sp. nov., foraminifers *Epistomina uhligi* Mjatl. (dominate), *Ophthalmidium cf. tenuissimus* Paalzow, *Spirillina* sp., *Globuligerina oxfordiana* Grig., spores. Separate beds split into beads-like beds of limestone concretions. Lenses of bivalve shell rock. Inside concretions ammonite shells are partially replaced by pyrite. Pyrite usually replaced by limonite is also dispersed in limestones in the state of small crystals. Thickness is 1,5–2 m.

2.2. Black clayey-bituminous shales with *Globuligerina oxfordiana* Grig. (1,5–2 m).

2.3. Black fine-grained limestones at the base and top – thin-bedded are presented by two beds (0,2–0,3 m) separated by clayey-bituminous shales. *Vinalesphinctes* (*Vinalesphinctes*) *troizkii*, V.(V.) *gomolitzkii*, V.(Roigites) *khusanovi*, V.(R.) *reimani* spp. nov. occur.

2.4. Black clayey-bituminous shales. At the microscope one can see thin (mm) alternation of microbeds of black non-transparent matter and clearly crystalline calcite. Shales contain abundant calcitic concretions sometimes making lensic limestone beds. Concretions and lenses are quite often forms from separate shells of ammonites and lenses of ammonite shell rocks. Thin shell rock beds formed from crushed shells are abundant in the upper part of the bed. Thickness - 6–8 m. Abundant fossils include: foraminifers *Glomospira* sp., *Ammobaculites* sp., *Marssouella cf. doneziana* Dain, *Nubeculinella ex gr. infraoolitica* Terq., *Quinqueloculina semisphaeroidalis* Danitch, *Q. cf. frumenta* Asbel et Danitch, *Epistomina uhligi* Mjatl., ammonites (at the lower part of the member) *Ochetoceras* (*Ochetoceras*) *canaiiculatum* (Buch), *Dichotomoceras* (*Dichotomoceras*) spp. indet, *Subdiscosphinctes ex gr. lucingae* (Favre), *S. ex gr. aeneas* (Gemmellaro), *Orthosphinctes* (*Pseudorthosphinctes*) cf. *polyplocoides* (Geyer), *O.*

(*Orthosphinctes*) aff. *tiziani* (Oppel), *O.* (*O.*) cf. *polygyratus* (Reinecke), *O.* (*O.*) *flscheri* Fantini Sestini et Assereto, *O.* (*O.*) aff. *obliqueplicatus* Dorn, 1930 (non Waagen, 1875), *O.* (*O.*) *praecox* (Spath), *O.* (*O.*) cf. *delgadoi* (Choffat), *Discosphinctes amanniyazovi* sp. nov., *D. subamanniyazovi* sp. nov., *Vinalesphinctes* (*Vinalesphinctes*) *troizkii* sp. nov., *V.* (*V.*) *gomolitzkii* sp. nov., *V.* (*V.*) *yuferevi* sp. nov., *V.* (*Roigites*) *khusanovi* sp. nov., *V.* (*R.*) *reimani* sp. nov., *Larcheria repmanae* sp. nov., *L. kutuzovae* sp. nov., *L. kurbatovi* sp. nov., *L. gubini* sp. nov., *L. lewitskii* sp. nov., *Epipeltoceras semimammatum* (Quenstedt), *Clambites* (*Neaspidoceras*) *sixtelae* sp. nov., *C.* (*Clambites*) *fortunatovae* sp. nov. At the base of upper third of section *Larcheria gubini* sp. nov., *Lithacosphinctes* cf. *lusitanicus* (Wegele) and a little bit higher *Lithacosphinctes* ex gr. *evolutus* (Quenstedt) occur. Except ammonites bivalves and brachiopods overgrowing huge ammonite shells and remnant of plants, fish (including fresh-water) are met.

Gaurdak Super Fm. J₃km₁

3.1. Dark gray fine grained not clearly bedded cavernous limestones with stylolites and crack pores. Thickness is 1,2 m. Limestones overlay shales with erosional boundary.

3.2. White sugar like gypsum transits into anhydrite in 1-2 m from the surface. Thickness is more than 120 m.

Interpretation - Shallow-marine, lagoon environment.

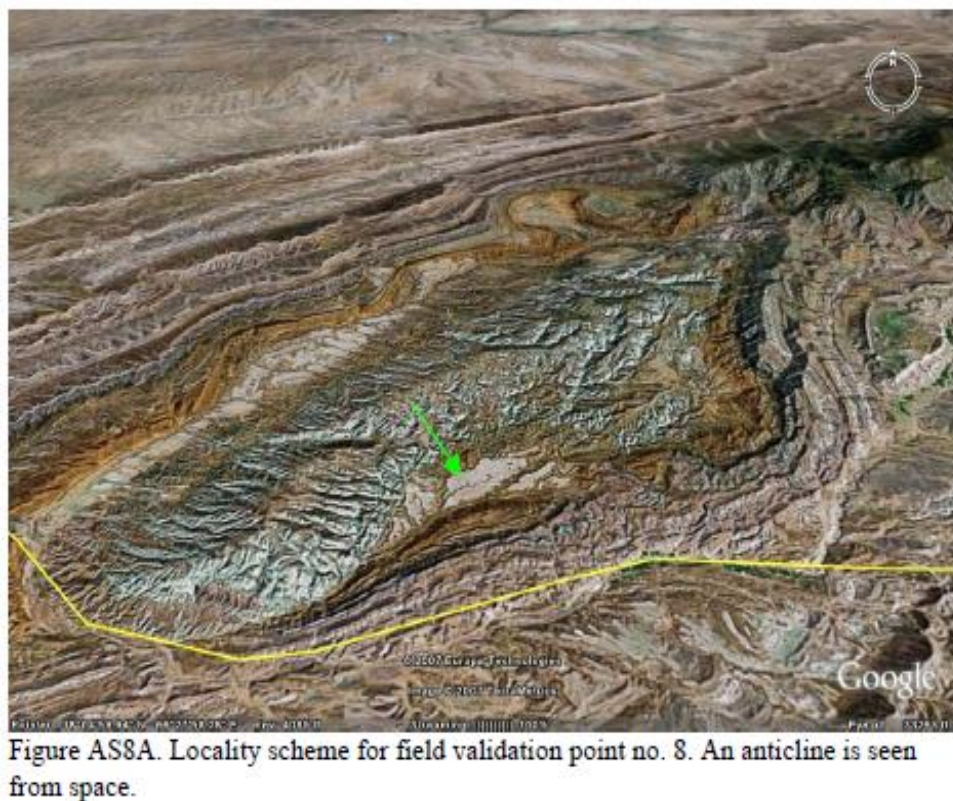
Structure: No data

Regional significance: This validation point is located within Gaurdak anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: black organic rich shales of Gudzhumtubegatang(skaya) Fm. contain up to 25–30% (Beznosov, Mitta, 1995) of organic matter (TOC)



ASIA 8



Locality 8: Karachagat Mt., Tubetagan ridge,
Kashkadaryin(skaya) province, SW Uzbekistan
Position (determined by Google Earth): 38.03.47.14
N, 66.27.20.61 E
Age: Late Callovian–lower Kimmeridgian

Sedimentology: *Description* (Beznosov, Mitta, 1995)

Described sequence of the Northern part of Gaurdak Mts. in details is repeated at the Eastern slope of Karachagat Mt. in Tubegatan Mts. (Fig. AS8A). At the exposed part of Zakharlin(skaya) Fm. Late Callovian *Binatisphinctes* (?) sp., Middle Oxfordian *Perisphinctes* (*Perisphinctes*) ex. gr. *martelli* (Oppel), *P. (P.)* sp. cf. *parandieri* Loriol, *Kranaosphinctes* occur. Near the top *Gregoryceras* sp. [*Gregoryceras tenuisculptum* Gygi.] was found. According to drilling data complete thickness of Kugitang Super Fm. here is 388 m, including: Gudzhumtubegatan Fm. 12–14 m, gypsum unit underlying bed R₁ 50–60 m, and Gaurdak Super Fm. about 663 m.

Interpretation - Shallow-marine, lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Tubetagan anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data

ASIA 9



Field trip. Validation points

Locality 9: Western slope of Kugitangtay ridge (Karluk Village), Lebap welayty, Eastern Turkmenistan

Position (determined by Google Earth): 37.41.43.14 N, 66.18.38.15 E

Age: Upper Oxfordian– Lower Kimmeridgian

Sedimentology: Description (Beznosov, Mitta, 1995) – Western slope of Kugitang-Tay Ridge

Western slope of Kugitang-Tay Ridge is “defended” (“armored”) by limestones of Kurek Fm. of Kugitang Super Fm. At the most deep gorges of the slope thin-bedded limestones of Zakharlin(skaya) Fm. and reef buildings of Kugitang reef complex are exposed. At the water-passes between gorges at the lower part of the slope the erosive remains of gypsum of base of Gaurdak Super Fm. overlay Kurek Fm. Complete section of Gaurdak Super Fm. are intersected by wells to the South and West from Kugitang-Tay Ridge. At the Southern submergence of the Ridge in the vicinity of Karluk Village the boundary beds of Kugitang and Gaurdak Super Fms. are presented by (Fig. AS9A, B):

Kugitang Super Fm. J₃o₃–?km₁

Kurek Fm. Thick and medium-bedded gray mainly cloddy (clumpy)–clotty limestones. Micritic and “eye-like” limestones and thin beds of calcarenites and calcirudites present. At the lower part thin beds of detrital limestones occur. Kurek Fm. lay upon abruptly divided surface of Kugitang reef complex covering it addendums and leaning to their slopes and filling the depressions of relief.

Thickness of Fm. strongly changes from 10-20 to 80 m. In the vicinity of Karluk Village upper part of Kurek Fm consists of:

1.1. Dark gray limestones unclearly bedded fine-grained with lenses and thin beds of carbonate gravelites. 6-8 m.

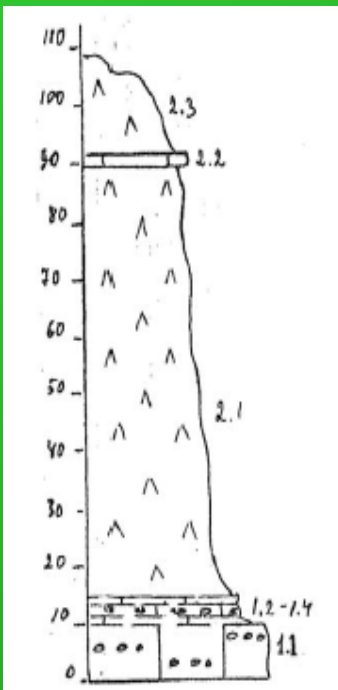


Figure AS7A (Beznosov, Mitta, 1995). Sequence of Kugitang and Gaurdak Super Fm.

1.2.Light gray fine-grained limestones. 0,4 m.

1.3.Light gray carbonate gravelite. 0,3 m.

Light gray fine-grained limestones. After unexposed part of 1,5 m thick **Gaurdak Fm. (J_3km_1) is exposed:**

2.1.White sugar-like gypsum. 70-80 m.

2.2. Gray algael limestones (bed R_1), about 1 m.

2.3.White sugar-like gypsum. 20 m.

Interpretation - Shallow-marine, lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data

Figure AS7B. View of Kugitang Mt. area.



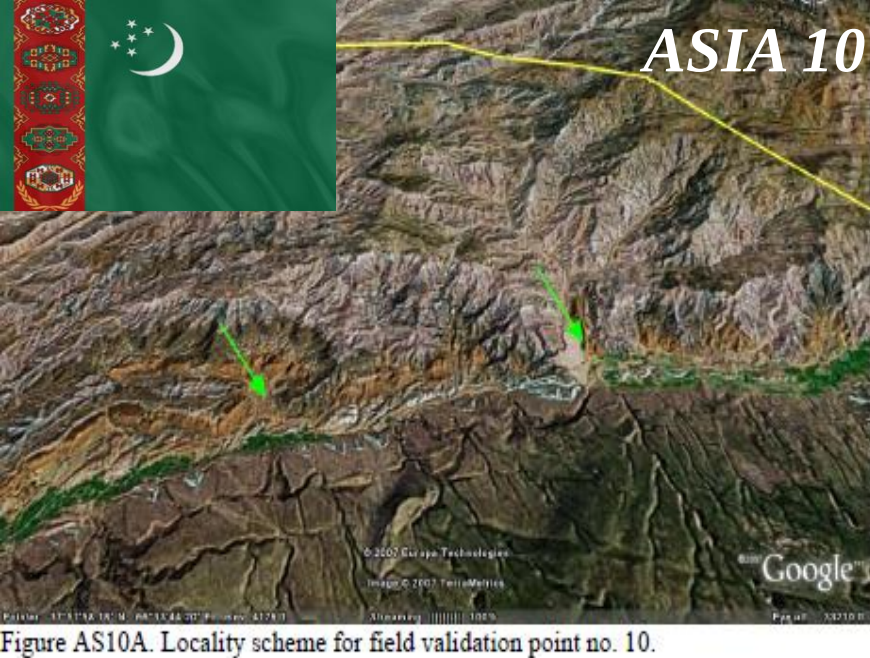


Figure AS10A. Locality scheme for field validation point no. 10.

Field trip. Validation points

Locality 10: Anyrchak mountain pass (Hodzshapil'ata village), Lebap welayty, Eastern Turkmenistan
Position (determined by Google Earth): 37.57.14.41 N, 66.35.23.08 E
Age: Upper Oxfordian–Lower Kimmeridgian

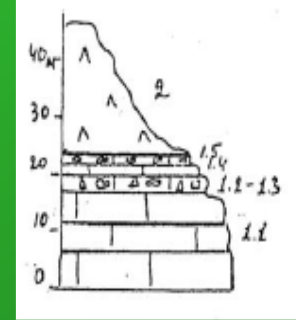


Figure AS10B (Beznosov, Mitta, 1995). Sequence of Kugitang and Gaurdak Super Fm.

Sedimentology: Description (Beznosov, Mitta, 1995) – At the North of Kugitang-Tay Ridge in the vicinity of Khodzshapil'ata sequence of Kugitang and Gaurdak Super Fms. boundary is presented by (Fig. AS10A–B):

1. Kurek(skaya) Fm., upper part.
 - 1.1. Gray and dark gray thick-bedded cloddy (clumpy)–clotty limestones comprise an “armored” (“defended”) slope under the settlement. Thickness is more than 15 m.
 - 1.2. Gray clastic limestone. 0,6 m.
 - 1.3. Carbonate gravelite at the upper part transiting into badly sorted conglomerate-breccia. 1,3 m.
 - 1.4. Dark fine-grained limestones with crack-like pores. 1 m.
 - 1.5. Carbonate gravelite. 0,3 m.

After 2 m thick unexposed interval rocks of **Gaurdak Super Fm. J₃km₁** can be seen:

2. White sugar-like gypsum. Visual thickness is more than 20 m.

Here Kurek Fm. is badly paleontologically characterized: innumerous traces of land reptiles – “dinosaures” on the bedding planes. Only one ammonite *Divisosphinctes* ex gr. *bifurcatus* (Quenstedt) is known. Dating was done basing on ammonite finds in deposits facially transiting into Kurek Fm. at the Sussyztay Ridge (read below) and by position within section.

Interpretation - Shallow-marine, lagoon, ?continental environment.

Structure: No data

Regional significance: This validation point is located within the Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data



Figure AS11A. Locality scheme for field validation point no. 11

Field trip. Validation points

Locality 11: Tangiduval'(skaya) hollow, Sussyztay Ridge, Hamkan river, Kashkadaryin(skaya) province, SW Uzbekistan

Position (determined by Google Earth): 38.06.09.49 N, 66.36.12.96 E

Age: Middle Oxfordian–Lower Kimmeridgian

Sedimentology: Description (Beznosov, Mitta, 1995) – To the North from Lyailyakansai Gorge on the Western slopes of Tangiduval and Kubatay Mts. limestones of Kurek Fm. start to be alternated with gypsum beds. On the right bank Khamkan–Pandzhob Gorge (Fig. AS11A, B) next sequence is exposed:

Kugitang Super Fm. J₃o₂₋₃

1. Kurek(skaya) Fm., upper part.

1.1.Gray and dark gray limestones thick-bedded fine-grained and pelitomorphic with small cavernas. More than 10 m thick.

1.2.Carbonate breccia. 0,8 m

1.3.Light gray fine grained cavernous limestones. 0,2 m.

1.4.Carbonate badly sorted gravelite with clastic parts of larger size. 0,3 m.

Fine-grained limestones with thin beds of calcarenite. 0,5 m.

Then unexposed part of 10 m thick is going.

Gaurdak Super Fm. J₃o₃–?km₁. Gardar(inskaya) Fm.

At the upper part of unexposed part some single exposures of white gypsum and limestones are observed.

2.1.Gray fine-grained thin-bedded limestones. 1 m.

2.2. Unexposed part of 1,5 m thick with rare gypsum.

J₃km₁. Lower Anhydrite Fm.

3. White gypsum more than 70 m thick.

Interpretation - Shallow-marine, lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Tubetagan anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data



Figure AS11B. View of area of point AS11.



Figure AS12A (Beznosov, Mitta, 1995). Sequence of Kugitang and Gaurdak Super Fm. at the Gardara Gorge

Locality 12: Gardara gorge, Suosgystay ridge, Kashkadaryin(skaya) province, SW Uzbekistan

Position (determined by Google Earth): 38.11.45.61 N, 66.47.34.26 E

Age: Lower Oxfordian–Lower Kimmeridgian

Sedimentology: Description (Beznosov, Mitta, 1995) – At the Northern part of Sussyztay Ridge at the upper part of gully coming down to Shurob Village, 1.5 km above the ruins of Gardara Village the following sequence is exposed (Fig. AS12A):

Kugitang Super Fm. J_3o_{1-2}

1. Kurek(skaya) Fm., upper part. Gray mainly thick-bedded cloddy (clumpy)–clotty and “eye”-like limestones with thin beds of clastic limestones to gravelites, oligotaxon bivalve and brachiopod shell rocks. Thickness is more than 100 m. In the interval of upper 20 m *Cardioceras* s.l. sp. indet. was found.

Gaurdak Super Fm. J_3o_3 –? km_1 .

2. Gardar(inskaya) Fm.

2.1. Gypsum with thin beds of gray porous limestones. 10–12 m.

2.2. Black cloddy with crack-like pores limestones. At the lower part with thin bed of light ouster shell rock. 4 m.

2.3. Sugar-like gypsum with thin beds (less than 0,5 m) of limestones with crack-like pores. 8–9 m.

2.4. Dark gray medium-bedded with “eyes” and thin beds of porous limestones. 3,5 m

2.5. Sugar-like gypsum. 8 m.

2.6. Gray pelitomorphic limestones with crack-like pores. 10 m.

2.7. White sugar-like gypsum make units of 1,5 m thick and alternate with pelitomorphic limestones with crack-like pores. 25–30 m.

2.8. Dark gray medium- and thick-bedded mainly pelitomorphic limestones with “eyes” of blue-green and thin beds of limestones with crack-like pores. In the middle and at the top contain thin beds of gypsum. 15–17 m.

2.9. White sugar-like gypsum make units of 0,5–15 m thick and alternate with subordinate beds (0,2–1,5 m) of gray pelitomorphic limestones with cavernas and crack-like pores. 40–45 m.

2.10. Gray and pale brown-gray irregularly thin- medium-bedded lithoclastic limestones with single thin bed of carbonate conglomerate at the top of the third member. 4–5 m.

In the cement of conglomerate *Ochetoceras* (?) sp. ind., *Lithasphinctes* cf. *lusitanicus* (Wegele, non Siemiradski), *Ardescia* sp. and bivalves occur.

2.11. Sugar-like gypsum make units of 3–5 m thick and alternate with beds (0,1–1,5 m) of gray pelitomorphic cavernous limestones. Up to 80 m. In the debris an undeterminable print of ammonite was found.

Interpretation - Shallow-marine, lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Tubetagan anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data



ASIA 13



Figure AS13A. Locality scheme for field validation point no. 13

Field trip. Validation points

Locality 13: South of Baisuntay ridge, Pas-Machay village, Kashkadaryin(skaya) province, SW Uzbekistan

Position (determined by Google Earth): 67.02.57.94 N, 38.19.05.64 E

Age: Oxfordian–Lower Kimmeridgian

Sedimentology: Description (Beznosov, Mitta, 1995) –

This section is last in the list of sections (no. 6–13) within Turkmenistan–Uzbekistan border belonging to Kugitang-Baisun folded zone (Figs. AS13A–B).

Kugitang Super Fm. J_3o_{1-2}

1. Kurek(skaya) Fm., upper part. Gray cloddy (clumpy)–clotty and “eye”-like limestones. Thickness is more than 35 m.

Gaurdak Super Fm. J_3o_3 –? km_1 .

2. Gardar(inskaya) Fm.

2.1. Carbonate breccia. 10–12 m.

2.2. Carbonate clays. 4–5 m.

2.3. Cloddy pelitomorphic limestones. 35 m.

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within the Tubetagan anticline belonging to Kugitang-Baisun folded zone (or Amu-Darya basin).

Petroleum systems information: No data

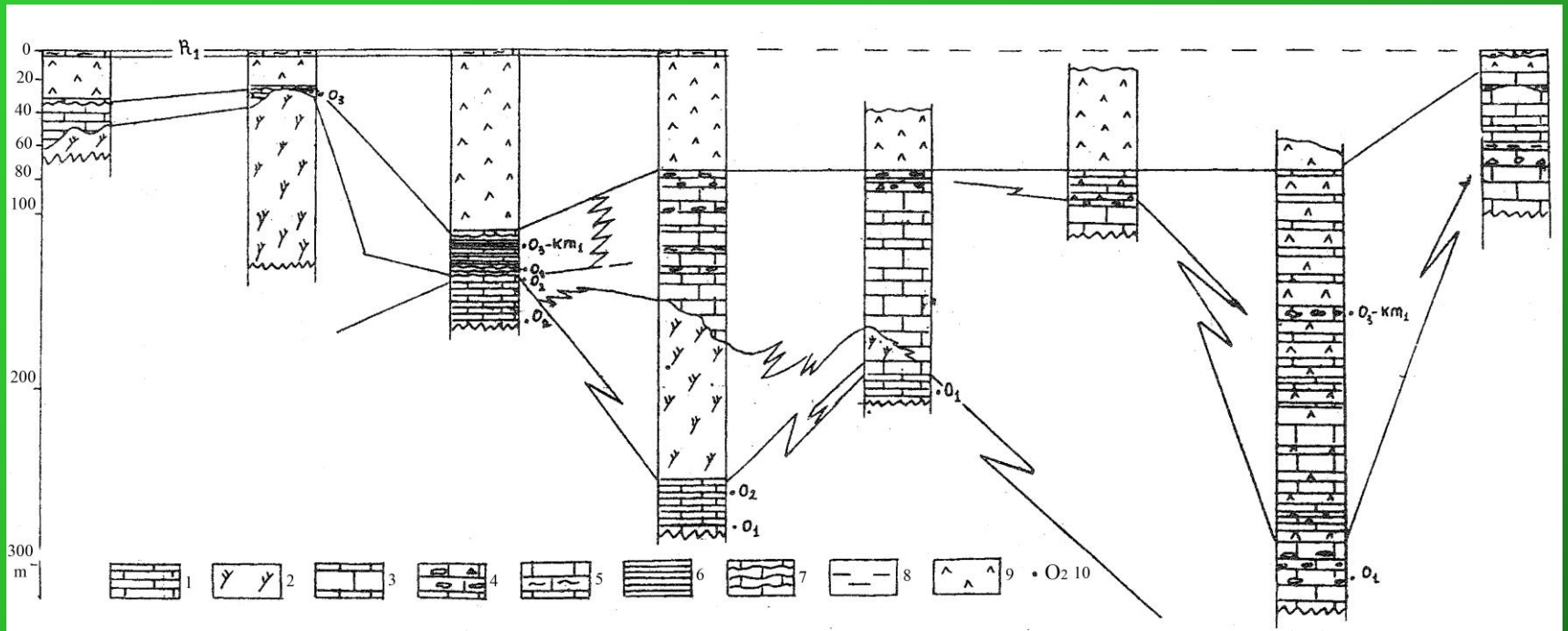


Figure AS13B. Correlational scheme for validation points no. 6–13 with facies boundaries (Beznosov, Mitta, 1995). Legend: A – SE slope of Gaurdak Mt. (point 6); B – Shurcha spring (point 7); C – NE slope of Gaurdak Mts. (point 8); D – Western slope of Kugitang-Tay Ridge (point 9); E – Khodzhapil'ta Village–Anyrchak mountain pass (point 10); F – Khamkan River (point 11); G – Gardara Gorge (point 12); H – South of Baisun-Tay Ridge, Pas-Machai Village (point 13); 1 – clayey, micrite thinly bedded limestones; 2 – reef limestones; 3 – thickly bedded clastic pelitomorph cloddy (clumpy)–clotty limestones; 4 – carbonate gravelites, conglomerates, breccias; 5 – thin beds of “algael” limestones (including oncoidal); 6 – black shales; 7 – nodular-bedded limestones splitting into concretion layers within loose carbonate bituminous mass; 8 – thinly bedded carbonate clays; 9 – gypsum (anhydrites); 10 – position and age of stratigraphic levels dated by ammonite finds

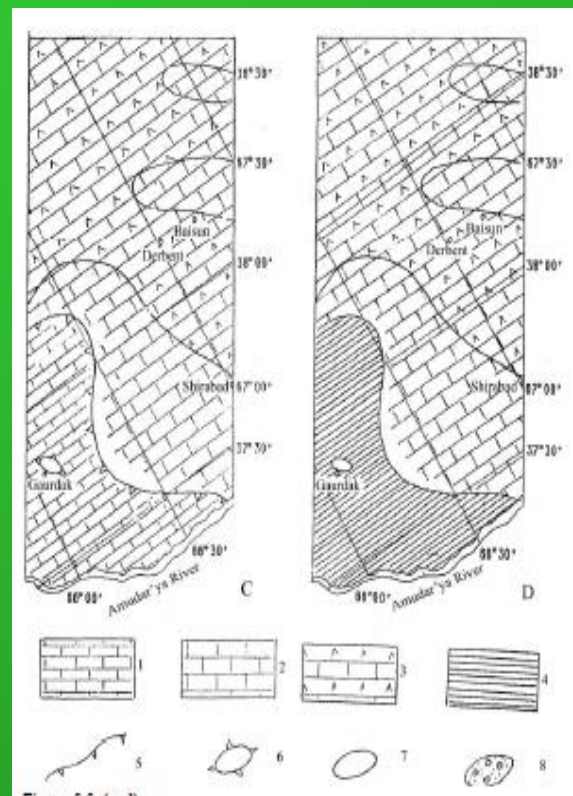
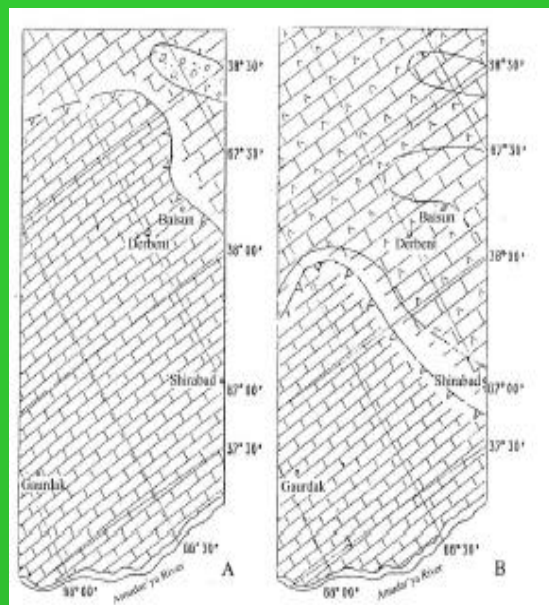


Figure 5.5. (Beznosov, Mitta, 1995). Paleogeographic schemes of SW Gissar for Oxfordian - beginning of Kimmeridgian: A - *lamberti-mariae* time; B - *cordatum-plicatilis* time; C - *transversarium* time; D - Late Oxfordian-beginning of Kimmeridgian. Legend: 1 - bottom of pericratonic basin (deep shelf - pseudoabyssal); 2 - lagoons with salinity close to normal, inwash bars and island (including within salted lagoons); 3 - high salinity lagoons; 4 - shallow basin-bay with low hydrodynamics of bottom waters; 5 - outer front of barrier-reef system; 6 - inner basinal reefs; 7 - eroded bars and islands within shallow bay; 8 - inwash bars and islands with accumulation of quartz and quartz-limestone and gravel deposits.

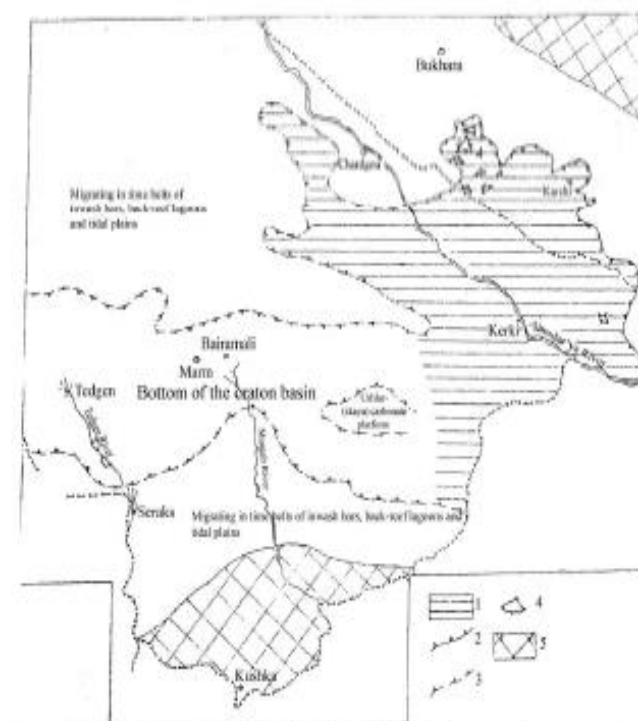


Figure 5.6 (Beznosov, Mitta, 1995). Position of black shale accumulation area relative to neighbour facies belts: 1 - black shale accumulation area; 2, 3 - outer fronts of live and dying barrier reef systems: 2 - according to drilling data and met at exposures, 3 - according to seismo-methods (geophysics); 4 - islands and bars above innerbasinal reefs intersected by drilling and met in exposures; eroded land.

Field trip. Validation points

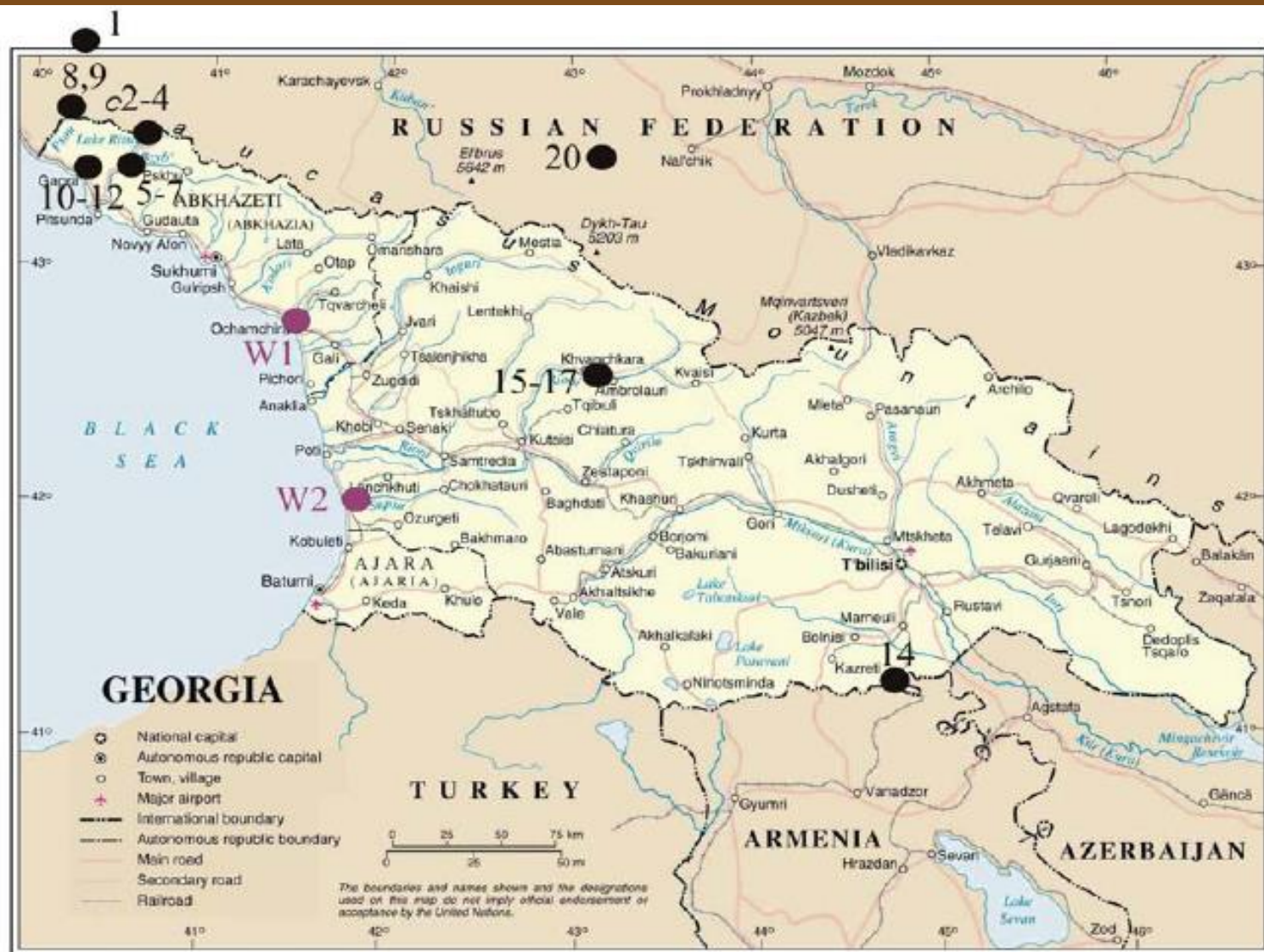


Figure 1. Scheme of location of field validation points (black) and 2 wells (purple).

The map displays Azerbaijan's borders with Georgia to the north, Russia to the northeast, Armenia to the west, and Iran to the south. Major cities are indicated by black dots, with Baku being the capital and largest city on the Caspian Sea. The Kura River is a prominent feature flowing through the country. The Nakhichevan Autonomous Republic is shown as a separate region to the southwest. The map includes a compass rose in the upper right corner and latitude/longitude coordinates along the edges.

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(805) 685-3100 www.maps.com

Locality 1: Vicinity of Kamennomostskiy Village, Adygeya Republic, Russia

Position: 44.16.51.8 N, 40.10.51.9 E

Age: Callovian

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Gerpegem(skaya) Fm. Paleontological and lithological characteristics of this Fm. is given in §3 (for Great Caucasus).

Interpretation – Medium deep marine environment.

Structure: No data

Regional significance:

This validation point is located within the Labin(skaya) zone

Petroleum systems

information: No data



Figure CS1A. Carbonate unit with member of siltstones and argillites. Plant detritus is presented in siltstones. Siltstones gradually transit into carbonates.



Figure CS1B. Argillites form hollows in the weathering profile, siltstones – “benches”.



Figure CS1C. On the fresh chip rock usually has more light color than on the weathered one.

Locality 2: Ritza Lake, Avadkhara region, Abkhazia

Position: 43.27.59.2 N, 40.32.09.8 E

Age: Upper Jurassic

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Carbonates of back-reef facies are exposed (Fig. CS2A–B). Fossils are presented mainly by corals of Upper Jurassic age. Many of them are badly preserved.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data



Figure CS2A. General view to outcrop.





Figure CS2B. A unit of a massive organogenous-clastic Upper Jurassic carbonates with separate corals 5 cm high can be found. Rock is re-crystallized, bedding is not seen.



Figure CS2C. A wild brown Russian bear near the Lake.

Locality 3: Ritza Lake, Avadkhara region,
Abkhazia

Position: 43.27.32.5 N, 40.32.48.5 E

Age: Upper Jurassic



Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – The most clastic and brecciated (comparably with previous point) facies of back-reef apron are exposed. Deposits are presented by brecciated limestones. Fossils are presented mainly by corals of Upper Jurassic age. Many of them are badly preserved.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data



Figure CS3A A unit of brecciated limestones. Cement was not found, so brecciation of the semi-consolidated sediment (?) could have happened.



Figure CS3B. The same, but enlarged.



Figure CS3C. A View to the next point (no. 4) from the point no. 3. – Canyon of Yupshara river



Locality 4: Bottom of the Yyupshara river canyon, region, Abkhazia

Position: 43.25.49.2 N, 40.31.33.6 E

Age: Upper Jurassic

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – The most outer part of the clastic carbonate back-reef apron is exposed (Figs CS4A–C). Deposits of undivided Upper Jurassic are first hundred meters thick. Limestones are massive sometimes thinly bedded with fossil fragments that can be easily seen. Horizons of dark bituminous limestones are met. A bed with innumerable free empty spaces not filled by sediment can be observed. Visual thickness is more than 150 m.

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data



Figure CS4A. General view to outcrop. Carbonate rocks form vertical cliffs of few hundreds meters high.



Figure CS4B. A unit of the massive limestones with bedding features. Thickness of beds is 50–150 cm.



Figure CS4C. Dark bituminous limestone. Empty spaces are free.



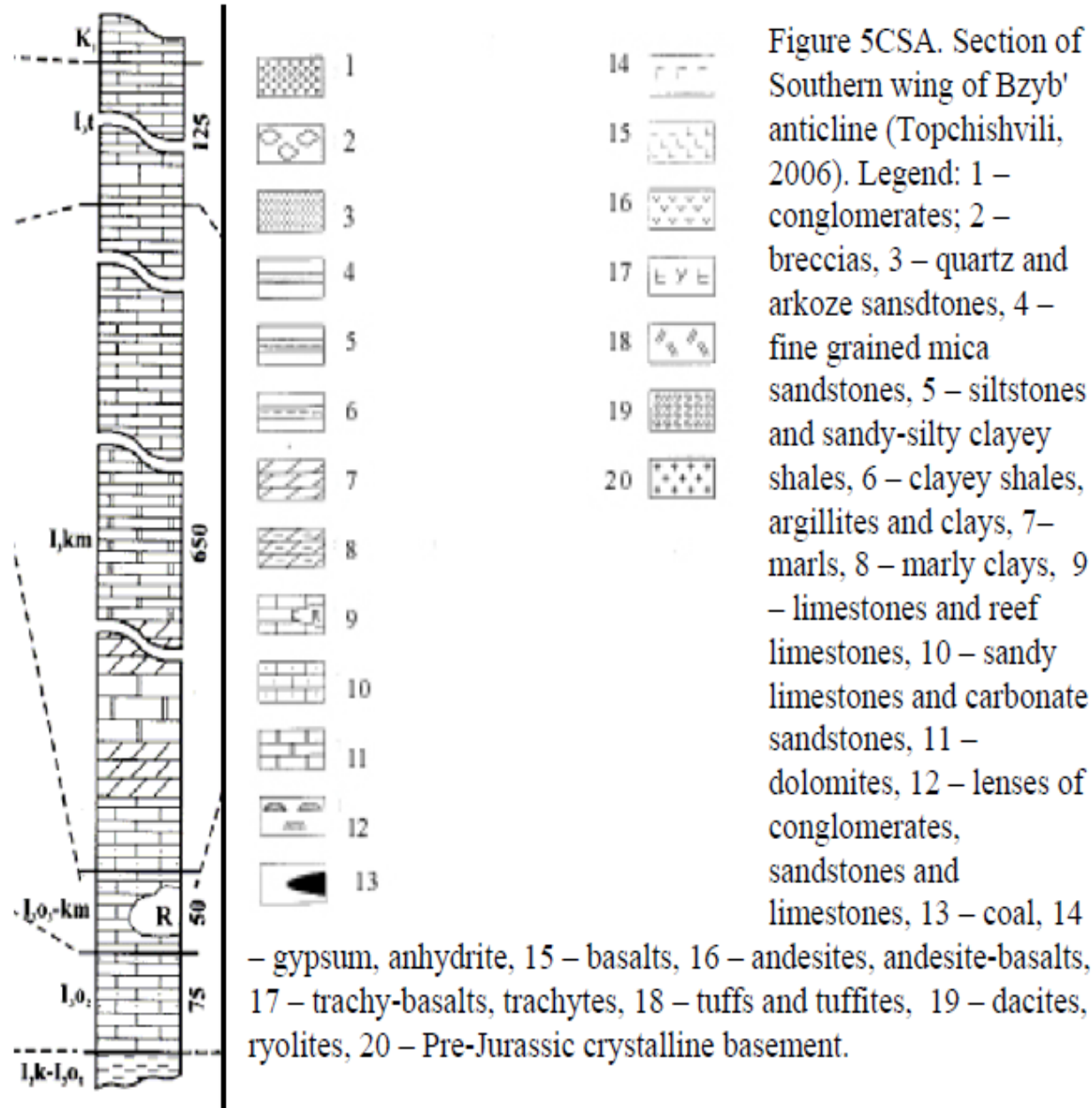
Locality 5: Rivers Bzyb' and Gega (junction) area, Avadkhara region, Abkhazia

Position: 42.22.09.0 N, 40.27.30.3 E

Age: Middle-Upper Jurassic

Sedimentology:

Description – Typical section of Aibginskaya Fm. (Fig. CS5A) is located in the Lower Bzyb' river in the tract Djirkhva where Bajocian porphyrite Fm. or Bathonian coal-bearing deposits are overlaid by rocks of Aibginskaya Fm. $J_2k_{1-3}-J_3O_1$ (Topchishvili et al., 2006).



Member 1. Lower Callovian. Greenish-gray fine grained conglomerate with porphyrite pebbles (1–5 m)
Member 2. Callovian – Lower Oxfordian. Gray fine-grained sandy clays with mollusc and plant fossils. Early Callovian ammonites *Indosphinctes* {*Indosphinctes*) *pseudopatina* (Par.et Bonar.), *I.(I.) choffati* (Par.et Bonar.), *I (I.) patina* (Neum.), *Choffatia* (*Choffatia*) *tilli* Mang. and Middle Callovian *Putealicerias* (*Putealicerias*) *lugeoni* (Tsyt.) are met. Discovered in this unit *Lunuloceras* (*Lunuloceras*) *compressus* (Quenst.) and *L. (L.) pavlovi* (Tsyt.) characterize Middle and Upper Callovian. Dinoflagellate complex: *Cleistosphaeridium varispinosum* Wool et Rid., *Valensiella ovula* Eisen., *Meiourogonya* *sp.*, *Chytroeisphaeridia chytroeides* Dow. et Sarj., *Sentusidinium* *sp.*, *Escharisphaeridia pocockii* Erk. et Sarj. From upper part of member Late Callovian and Early Oxfordian bivalves *Camptonectes viridunensis* (Buv.), *Lima laeviuscula* (Sow.), *Ltumida* Roem., *L. streitbergensis* (d'Orb.), *Trigonia perlata* (Sow.) are known. Thickness is 90–120 m.

This interval of section is overlaid by Middle and Upper Oxfordian sandstones (Topchishvili et al., 2006). To the North at the Lower Gega River (right tributary of Bzyb') near karst waterfalls anticline is exposed with core filled by porphyrite Bajocian. It is transgressively covered by carbonate breccia-conglomerates with fragments of porphyrites. Callovian ammonites *Choffatia* (*Choffatia*) *cf. waageni* (Teiss.), *C. (Grossouvria) subtilis* (Neum.), *Putealicerias* (*Zieteniceras*) *pseudocracoviense* (Tsyt.), *Lissoceras psilodiscus* (Schl.), *Euaspidoceras appeninicum* (Liet.) and also Oxfordian belemnite *Hibolites cf. latesulcatus* (d'Orb.) and bivalve *Chlamys splendens* Dollf. are distributed.

This member of breccia-conglomerates of 3–3.5 m thick was accumulated probably within all Callovian–Early Oxfordian. To the South and to the North thickness of Callovian deposits considerably increases. N.G. Khimshiashvili (1957) considered that sedimentation proceeded at the submarine rise that is why terrigenous input was absent. Another point of view belongs to V.I. Kurochkin (1938, 1940) and N.S. Bendukidze (1964). They decided that shells of cephalopods and bivalves were re-deposited and breccia-conglomerates present the basal bed of massive Oxfordian limestones (Topchishvili et al., 2006).

Callovian Sea quickly transgressed to the South into Upper Bzyb' area (Reshevie river, Dou mountain pass and others), where near the shoreline macrocephalitids and other ammonites, bivalves comfortably developed. Here Bajocian deposits are transgressively covered by conglomerates, gravelites, siltstones, sandy clays with lenses and thin beds of sandy limestones (thickness 60–80 m). Here Early Callovian: *Dolikephalites subcompressus* (Waag.), *Macrocephalites* ex gr. *rotundus* (Quenst.), *M. canizarroi* (Gemm.), *M. madagascariensis* Lem., *Indocephalites caucasicus* (Djan.), *Pleurocephalites tumidus* (Rein.), *Kamptokephalites lamellosus* (Sow.), *K. colchicus* (Djan.), *Kheraicerias* (*Kheraicerias*) *bullatus* (d'Orb.), *Cutchisphinctes* cf. *altiplicatus* (Waag.), *Choffatia* (*Subgrossouvria*) *recuperoi* (Gemm.), *Homoeoplanulites* (*Homoeoplanulites*) *balinensis* (Neum.), *H. (H.) furculus* (Neum.), *H. (Parachoffatia) funatus* (Opp.), *Indosphinctes* (*Indosphinctes*) *pseudopatina* (Par. et Bonar.), *I. (I) choffati* (Par. et Bonar.), *I. (I) urbanus* Spath., *Flabellisphinctes* (*Flabellisphinctes*) *villanyensis* (Till), *Hecticoceras* (*Hecticoceras*) ex gr. *hecticus* (Rein.), and also Mid-Callovian ammonites: *Binatisphinctes* (*Okaites*) *rossica* (Siem.), *Lunuloceras* (*Lunuloceras*) *compressus* (Quenst.) and innumerable bivalves are found. At Lower Reshevie river in gray weakly carbonate siltstones Early Callovian dinoflagellates: *Caddasphaerahalosa* Fent. et al., *Lithodinia bathonica* Conway, *Meiourogoniaulax callomonii* Sarj., *Cleistosphaeridium varispinosum* Wool. et Rid., *Adnatosphaeridium caulleryi* Will. et Dow., *Chlamydophorella* sp., *Chythroeisphaeridia chythroeides* Dow. et Saej., *Ctenidodinium ornatum* Defland typical for this stage foraminifers are met (Topchishvili et al., 2006).

Within Southern wing of Bzyb' anticline on the right bank of Bzyb' river along the highway the following section is exposed (Topchishvili et al., 2006).



Figure CS5B. Gorge of Bzyb' river. J₃km. Limestones make up vertical cliffs. A unit of re-crystallized limestones can be observed. Horizons of bituminous limestones can be seen. Calcitic lodes cut the bituminisation. Bituminisation is secondary but before the stage of deformation (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report)

Member 1. J₃O₂ Whitish-gray brittle thin bedded limestones (15 m). Probably on the same level in tract Djirkhva *Alveosepta* cf. *jaccardi* (Schr.) was found.

Member 2. J₃O₂ Alternation of gray hard medium- and thin-bedded limestones with thick-bedded limestones and sandy limestones (13 m). At the upper part sandstones beds appear.

Member 3. J₃O₂ Grayish-white sometimes pinkish medium- and thin-bedded hard crystalline and sandy limestones (30 m).

Member 4. J₃O₂ Grayish, medium-bedded very hard pelitomorphic limestones (2 m).

Member 5. J₃O₂ Grayish-pink medium- and thick-bedded hard crystalline sandy limestones (15 m). Probably here *Pseudomelania heddingtonensis* (d'Orb.), *Lopha solitaria* (Sow.), *Plesiodiceras uzuntachi* Peel. were found.

Member 6. J₃O₃–km Light gray massive reef limestones with *Calamophylliopsis flabellum* (Mich.) (40–50 m) (Topchishvili et al., 2006).

At the Lower Gega River near karst waterfalls thick-bedded and massive crystalline organogenous sometimes brecciated limestones are exposed (150–160 m) with Middle and Late Oxfordian microfauna: *Pseudocyclamina* cf. *lituus* Yok., *Planularia* cf. *laminosa* Schw. and *Spirillina* cf. *kuebleri* Mjatl. Also late Oxfordian corals *Dimorphastraea lamellosa* Sol. and *Aplosmilia semisulcata* (Mich.) are met (Topchishvili et al., 2006).

Typical section of Kimmeridgian is located within Southern wing of Bzyb' anticline in the Gorge of Bzyb' river in the tract Djirkhva (Topchishvili et al., 2006).

Member 1. J₃km. Alternation of limestones, marly and sandy limestones and marls with thin beds of bluish-gray clays with *Avicula gessneri* Thurm., *Parallelodon rhomboidale* (Contej.), *Lucina plebeja* Contej., *Cardium colineum* Buv., *Plagiostoma tumida* (Roem.). Thickness – 100 m.

Member 2. J₃km. Alternation of marly limestones, marls and dolomites with clayey sandstones and conglomerates (150 m).

Member 3. J₃km. Bedded dolomitized and sandy limestones. From this member but in the valley of Khipsta river
Hinnites cornuelli Lor., *Gervillia tetragona* Roem., *Trigonia spinifera* (d'Orb.), *Arcomytilus pectinatus* (d'Orb.) Thickness – 200 m.

Member 4. J₃km. Gray and brown bituminous limestones. In the core of wells from Blaburkhva village from this member *Chlamys subtextorius* Munst., *Hinnites inaequistriatus* (Voltz.), *Exogyra virgula* (Defr.) were determined. Thickness – 200 m (Topchishvili et al., 2006).

To the North at the Lower Gega river above well characterized by fossils upper Oxfordian thick bedded and massive organogenous limestones a member without determinable fossils of medium- and thick-bedded, weakly bituminous sometimes dolomitic limestones of 100 m thick of probably Kimmeridgian age is exposed (Topchishvili et al., 2006).

Probably Kimmeridgian part of the section can be observed at the Bzyb' and Gega junction area (Fig. CS5B–D). Here clastic facies of reef apron occur (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) .

At the Lower Gega river near the karst waterfalls Kimmeridgian weakly bituminous dolomitized limestones are overlaid by member of marls, marly limestones and sugar-like dolomitized limestones with chert concretions (150–160 m). At the upper part Tithonian bivalves and brachiopods *Rhynchonella asteriana* Orb., *Chlamys arotoplica* Gemm., *C. quenstedti* Blake, *Diceras speciosos* Munst., *D. staszicii* Zeusch. occur (Topchishvili et al., 2006).



Figure CS5C. On the fresh chip can be seen that limestones are dark and bituminous.



Figure CS5D. Member of non-bituminous limestones.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information is given in §6, Table 1

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information is given in §6, Table 1



Locality 6: tributary of the Goluboye ("Blue") Lake, Avadkhara region, Abkhazia

Position: 43.21.03.6 N, 40.24.40.3 E

Age: Upper Jurassic – Neocomian (?)

Sedimentology:

Description) – At the Northern wing of Bzyb' anticline near Goluboye ("Blue") Lake Tithonian carbonate rocks (Fig. CS6A–F) building steep cliffs of Bzyb' Gorge. At the lower part they are presented mainly by bedded dolomite and crystalline limestones (180 m). Upper part of the section is built from gray bituminous sometimes bedded breccia-like limestones (30 m) (Topchishvili et al., 2006). Some part of the section can coincide to Neocomian



Figure CS6A. A view to Goluboye ("Blue") Lake. A steep slope comprised by Kimmeridgian limestones can be seen.

(Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report). In the point a body of the reef massif is exposed.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data V.A., Bolotov S.N., Nikul'shin A.S. – oral report). In the point a body of the reef massif is exposed.



Figure CS6B. A unit of massive and bedded carbonates. Limestones are to a different extent bituminous.



Figure CS6C. Fissured bedded limestones



Figure CS6E. Chert concretion inside limestone



Figure CS6D. Fresh chip of the bituminous limestone



Figure CS6F. Calcitic lodes cross the bituminisation



Locality 7: Bzyb' river, Avadkhara region, Abkhazia

Position: 43.20.43.4 N, 40.24.45.6 E

Age: Upper Jurassic

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – In the point a slide limestone body is exposed (Fig. CS7A). Geological setting is analogous to point number 5.

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information:

Strongly poriferous limestone having a distinct gas smell (Fig. CS7B). Other additional data is given in §6, Table 1



Figure CS7A. A view to a carbonate massif.



Figure CS7B. Strongly poriferous limestone having a distinct gas smell.

Locality 8: old road near tunnel of new Adler – Krasnaya Polyana highway, Adler region, Russia

Position: 43.35.38.4 N, 40.01.03.9 E

Age: Upper Jurassic

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – In the point a body of reef is exposed. Point is analogous to point no. 6. Unit of massive re-crystallized limestones with badly determinable corals can be seen (Figs. CS8A–B). Features of bedding exist. Rocks are to a different extent fissured.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the barrier reef zone Akhcu-Katsirkha (See Fig. 3.5)

Petroleum systems information: No data



Figure CS8A. General view to exposure.



Figure CS8B. Massive re-crystallized limestones with badly determinable corals.

Locality 9: Waterfall Devich'i Sleozy ("Girl's tears"), Adler – Krasnaya Polyana region, Russia

Position: 43.39.10.4 N, 40.09.10.5 E

Age: Tithonian – (?) Neocomian

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Agepstynskaya Fm. (lithological and paleontological characteristics is given in §3). A unit of argillite and turbiditic sandstone alternation (Figs CS9A–E). Cleavage is found within the unit. Turbiditic bedding and mechanoglifs are typical for sandstones.

Interpretation – Deep-water environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Novorossyisko-Lazarev(skaya) zone (See Fig. 3.5)

Petroleum systems information: No data



Figure CS9A. View to waterfall.



Figure CS9B. Gentle folds.



Figure CS9D. Sandstones within argillites.



Figure CS9C. The same but enlarged.



Figure CS9E. A member with dominative argillites with rare thin sandstone beds.

Field trip. Validation points

CS10

Locality 10: Zhovekvara River, Gagry region, Abkhazia

Position: 43.19.55.9 N, 40.13.28.7 E

Age: Tithonian

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Unit of bituminous brecciated limestones with small portions of solid bitumen inside empty spaces and fissures of Asphalt Fm. (this Fm. is absent in Jurassic of Caucasus, 1991). It presents back-reef facies. Limestones do not demonstrate bedding.

Interpretation - Shallow-marine environment.

Structure: Unit is folded, tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information is given in §6, Table 1.



Figure CS10A. Brecciated limestone.



Figure CS10B. Brecciated limestone filled by bitumen.



Figure CS10C. Bitumen fills fissures. Oil filled more late tectonic fissures and other empty spaces



Figure CS10D. The same as previous.



Figure CS10E. Vertical fissures filled by bitumen.



Figure CS10F. Spots of bitumen inside a rock.

Field trip. Validation points

CS11

Locality 11: Zhovekvara River, Gagry region, Abkhazia

Position: 43.20.41.0 N, 40.14.10.7 E

Age: Tithonian

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Asphalt Fm. (this Fm. is absent in Jurassic of Caucasus, 1991) presents back-reef facies. Unit of bituminous brecciated limestones with small portions of solid bitumen. Inside empty spaces and fissures (Fig. CS11A–F). Limestones do not demonstrate bedding.

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information is given in §6, Table 1



Figure CS11A. A view to a unit of dark brecciated bituminous limestones. Bedding elements can be seen.



Figure CS11B. Empty spaces were filled by asphalt.



Figure CS11D. Asphalt appeared after calcite have partially filled empty spaces.



Figure CS11C. Small portions of bitumen filled fissures and empty spaces.



Figure CS11E. Asphalt is surrounded by calcite.



Figure CS11F. Brecciated limestones firstly were filled by calcite and then by asphalt (oil)

Locality 12: Zhovekvara River, Gagry region, Abkhazia

Position: 43.20.10.4 N, 40.13.37.4 E

Age: Tithonian – Neocomian (?)

Sedimentology:

Description (Nikishin A.M., Lavristchev V.A., Bolotov S.N., Nikul'shin A.S. – oral report) – Asphalt Fm.

Unit of bituminous massive limestones with features of bedding.

Interpretation - Shallow-marine environment (back-reef facies).

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the Dzhirvkhva-Akhibokh(skaya) zone (see Fig. 3.5)

Petroleum systems information is given in §6, Table 1.



Figure CS12A. View of outcrop.



Figure CS12B. Fresh chip of the bituminous limestone.



Figure CS12C. An assumed fissure filling by oil.



Locality 13: Kyapaz Mt., Khanlar region, Azerbaijan

Position (of Khanlar region centre determined by Google Earth): 40.34.59.04 N, 46.19.14.20 E

Age: Callovian–Oxfordian

Sedimentology:

Description (Abdulkasumzade, 1988) – Kyapaz(skaya) Fm. conformably covers Bathonian deposits and is overlaid by Gulistan(skaya) Fm. Total thickness – 500 m.

Member 1. J₂k₁ Gray, dark gray, fine- and coarse-grained carbonate sandstones with *Lunuloceras* (L.) *lunuloidea* Kil., *Velate bonjuri* Lor., *Bositira buchi* (Roem.), *Montlivaltia labechei* Edw. et H. (29 m).

Member 2. J₂k₁ Fine-grained tuff conglomerate (2 m).

Member 3. J₂k₁ Alternation of greenish-gray fine-grained carbonate, clayey sandstones, clays with carbonate tuff sandstones and tuff breccias with *Pseudophylloceras kuderrnatschi* (Hauer), *Entolium vitreum* Roem., *E. demissum* (Phill.), *Radulopecten fibrosus* Sow., *R. laurae* (Etall.) (30 m).

Member 4. J₂k₁ Coarse-grained tuff conglomerate (2 m).

Member 5. J₂k₂ Alternation of coarse-grained tuff sandstones, fine-grained gray sandstones with greenish tuffs. Thin gravelite and tuff breccia beds exist. Some coalificated plant remnants occur (15 m).

Member 6. J₂k₂ Alternation of fine-grained tuff sandstones, clayey sandstones with tuff conglomerates with *Coelastarte incerta* Pčel., badly preserved genuses *Phylloceras* and *Hecticoceras*, *Grammatodon keiserlingi* (Orb.), *Ctenostreon proboscideum* (Sow.), *Radulopecten subinaequicostatus* (Kas.), *R. fibrosodichotomus* (Kas.) *Velate bonjuri* Lor., *Astracolus polonica* Wisn., *Lenticulina pseudocrassa* Mjatl., *Ophtalmidium arieniforme* Buk. (16 m).

Member 7. J₂k₂ Grayish-brown hard carbonate sandstones, coarse-grained tuff sandstones (12 m).

Member 8. J₂k₂ Grayish-brown fine-grained sandstones with thin beds of hard sandy limestones with *Spondylopecten* (P.) *subspinosus* (Schloth.), *Pseudomelania* aff. *hedonia* (Orb.), *Hecticoceras* sp., badly preserved corals and crinoids (40 m).

Member 9. J₂k₂ Alternation of gray, dark gray coarse-grained sandstones, tuff sandstones, tuff breccias (72 m).

Member 10. J₂k₃ Fine- and coarse-grained tuff sandstones, dark gray, brown argillites with *Ptychophylloceras euphyllum* (Naum.), *Entolium spathulatum* Lor., *E. demissum* (Phill.), *Chlamus episcopalis* Lor., *Spondylopecten* (*P.*) *subspinosus* (Schloth.), *Plagiostoma subrigidula* (Schlip.), *Pseudolimea duplicata* (Sow.), *Ctenostreon pectiniforme* (Schloth.), *Planularia foliacea* Schloth., *P. tricostrata* Mjatl., *Lenticulina tumida* Mjatl., *Lenticulina uhligi* Wisn. (70 m).

At Khatunbulag Gorge (NE slope of Kyapaz Mt.) from the lower part of the section Lower Callovian fauna was collected: *Choffatia* aff. *radashensis* Djan., *Ch. cf. choffat* Par. *Ch. recouperoi* Gemm., *radashensis* (Djan.), *Calliphylloceras demidoffi* (Rouss.). 60 m higher from described interval *Pseudolimea duplicata* (Sow.), *Plagiostoma subrigidula* (Schlip.), *Montlivaltia cf. gregoryi* Abl. and others occur.

Member 11. J₂o₁ Alternation hard, fine- and coarse-grained sandstones. Few sandy limestones exists with *Entolium cingulatum* Goldf., *Radulopecten laurae* (Etall.), *Tretospira abichi* Neum. and others (100 m).

Member 12. J₂o₁ Alternation of gray tuff siltstones, fine- and coarse-grained tuff sandstones with thin beds of hard sandstones. At the upper part 3 conglomerate beds occur. At tuff sandstones *Camptonectes* (*C.*) *bauchi* Roem., *C. (C.) viridunensis* (Buv.), *Heligmus* aff. *polyptychus* Declon, *Modiola* aff. *tulipaeai* Lam., *Pleuromytilus perplicatus perplicatus* Thum. and single corals were collected (40 m).

Member 13. J₂o₁ Alternation of gray tuff siltstones, fine- and coarse-grained tuff sandstones with thin beds of ferruginous sandstones. At tuff siltstones plant remnants are met (38 m) (Abdulkasumzade, 1988).

From Lower Oxfordian interval of section corresponding to beds with “*Ceratolamarckina*” *speciosa* — *Lenticulina brueckmanni* foraminiferal complex including: *Marssonella jurassica* Mitjan., *Lenticulina brueckmanni* (Mjatl.), *L. compressaeformis* (Paa1z.), *L. samaraensis* Mjatl., *L. aequilateralis* (Kub1. et Zw.), *L. quenstedti* (Gumb.), *L. russiensis* (Mjatl.), “*Ceratolamarckina*” *speciosa* (Dain), *Pseudolamarckina rjasanensis* (Uhlig), *Trocholina iransversarii* Paa1z., *Globuligerina oxfordiana* (Grig.) and some others was establish. Rare foraminifers are irregularly distributed along the section. Typical species: *Marssonella jurassica*, *Lenticulina brueckmanni*, *L. quensiedli*, “*Ceratolamarckina*” *speciosa*, *Trocholina transversarii*, *Globuligerina oxfordiana*.

Lower boundary of beds is marked by appearance of *Lenticulina brueckmanni* and *Globuligerina oxfordiana* — at this level typical Late Callovian species *Lenticulina tumida*, *Epistomina elschankaensis* and others disappear (Practice, 1991).

Then sequence demonstrates exposure of Gulistan(skaya) Fm., corresponding to Middle Oxfordian–Lower Kimmeridgian (Abdulkasumzade, 1988):

Member 14. J₂O₂₋₃ White and light gray fine-grained crystalline limestones with *Radulopecten (F.) buigneri* (Desh.), *Chlamys viminea* (Sow.), *Spondylopecten (S.) erinaceus* (Buv.), *Diceras subbourgeati* Pchel. (70 m).

Member 15. J₂O₂₋₃ Pinkish-white fine-grained cherty-dolomitic limestones with badly preserved corals (70 m).

Member 16. J₂O₂₋₃ Gray, yellowish-gray hard fine- and “dust”-grained dolomites (60 m).

Member 17. J₂O₂₋₃ Grayish-brown organogenous hard fine- and “dust”-grained limestones (43 m).

Member 18. J₂km₁ Marblized sandy organogenous limestones with thin beds of tuff with *Cryptocoenia tabulata* Koby, *Stylina excelsa* Etall. (57 m).

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within the Khram(skaya) subzone of Somkheto-Karabakh zone(see Fig. 3.5)

Petroleum systems information: No data

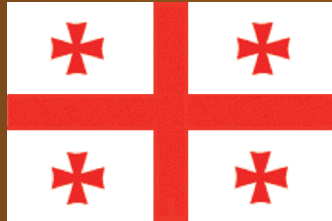
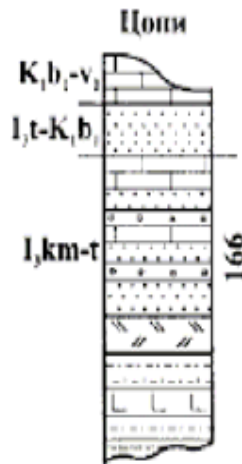
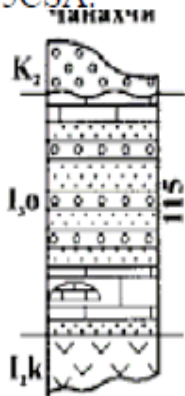


Figure 14CSA. Sections of Late Jurassic deposits (Topchishvili et al., 2006) of Lesser Caucasus (Lokhsko-Karabakh(skaya) zone): Chikhakh (left) and Tcopi (right). For the Legend – see Fig. 5CSA.



Locality 14: Vicinity of Chanakhchi Village, right bank of Shulaverchai River, Shulaveri region, Georgia

Position (determined by Google Earth): 41.14.16.10 N, 44.41.01.65 E

Age: Oxfordian–Kimmeridgian

Description – Oxfordian deposits are established conventionally (Toptishvili et al., 2006, Fig. CS14A) by correlation with neighbor regions.

Member 1. J₃o. Loose weathered thick-bedded sandstones (15 m).

Member 2. J₃o. Medium- and thick-bedded limestones with abundant chert lenses (30 m).

Member 3. J₃o. Sandstones and gravelites with 2 beds of red conglomerates with rare pebble (40 m).

Above gravelites and sandstones are exposed which are with erosion overlaid by basal conglomerate of Upper Cretaceous deposits.

On the North of Lokhsko-Karabakh(skaya) zone to the East from Lokh(skyi) addendum below Cenomanian deposits Upper Jurassic–Lower Cretaceous rocks occur. The most complete section can be seen near Eastern end of Tcopi village:

Member 1. J₃km-tt. Light gray siltstones and diabases (26 m).

Member 2. J₃km-tt. Gray carbonate tuffite with thin beds (up to 0.4 m) of crystalloclastic tuff of purple color with molluscs: *Ptygmatis submirabilis* Pčel and *Cryptoplocus (Conoplocus) subpiramydalis* (Muenst) 20 m.

Member 3. J₃km-br (?). Alternation of weakly colored gray medium-size clasted tuffs, tuff sandstones and tuff breccias with rare beds of sandy and marly limestones. Member contains Kimmeridgian – Berriasian association of foraminifers: *Pseudocyclaminna* ex. gr. *lituus* (Yok.), *P.* ex. gr. *sphaeroidalis* Hott., *Everticyclaminna* ex. gr. *virguliana* (Koechl.), *Nautiloculina* ex. gr. *oolithica* Mohl. (120 m).

Last member probably also includes Lower Berriasian because the overlaying volcanic-carbonate deposits are dated by foraminifers as Late Berriasian–Early Valanginian. To the West from Tcopi Village to Khojorii village at the base of marbleized and marly limestones the typical Kimmeridgian complex of foraminifers occur:

Alveosepta jaccardi (Schr.), *Mesoendothyra* cf. *izjumiana* Adin., *Pseudocyclamina* cf. *lituus* (Yok.), *Torinosuella* cf. *peneropliformis* (Yabe et hanz.), *Nautiloculina* cf. *oolithica* Mohl., *Trocholina* cf. *elongata* (Leup.) and others. Nearly analogous complex present in NE Armenia along the left side of gorge of Agetev River inside volcanic-sedimentary deposits including rare limestone beds. This fact prove the idea that during late Jurassic nearly within whole Lokhsko-Karabakh(skaya) zone a unite biofacial regime of sedimentation existed.



Field trip. Validation points

CS15

Locality 15: Korta Village, Ambrolauri region, Georgia

Position (approximately determined by Google Earth): 42.45. N, 41.30. E

Age: Callovian–Kimmeridgian

Sedimentology:

Description – Brown shale-like clays more than 100 m thick of probably Bathonian age are overlaid by (Topchishvili et al., 2006):

Member 1. J_2k_1 Greenish-gray sandy clays and clayey sandstones with carbonate concretions and following fossils: *Macrocephalites macrocephalus* (Schloth.), *M. canizarroi* Gemm., *Indocephalites caucasicus* (Djan.), *Dolikephalites subcompressus* (Waag.), *Pleurocephalites tumidus* (Rein.), *P. subtumidus* (Waag.), *P. pila* (Nik.), *Kamptokephalites lamellosus* (Sow.), *K. subtrapezinus* (Waag.), *K. colchicus* (Djan.), *Kepplerites* (*Gowericeras*)

gowerianus (Sow.), *Choffatia* (*Subgrossouvria*) *recuperoi* (Gemm.) Quantity of sandstones gradually increases in the upper part of member. Thickness — 150—200 m (Fig. 15CSA).

Member 2. J_2k_{2-3} — J_3o_{1-2} Yellowish-gray carbonate sandstones with thin marl beds (“Korta beds”). Thickness — 35—40 m (Fig. 15CSA–B).

At the base Middle Callovian *Putealicerias* (*Putealicerias*) cf. *svevum* (Bonar.), *P. (P.) metomphalum acuticosta* (Tsyt.), *P. (Zieteniceras) evolutum* (Lee), *Lunuloceras* (*Lunuloceras*) *lunula* (Rein.) were met. Higher *Peltoceras athleta* (Phill.), *Euaspidoceras ferrugineus* Jean and innumerable Phylloceratinae cephalopods occur. “Korta beds” are characterized by Late Callovian, Early and Middle Oxfordian

ammonites: *Quenstedtoceras lamberti* (Sow.), *Q. henrici* Douv., *Kosmoceras* (*Gulielmiceras*) cf. *proniae* Teiss., *Lunuloceras* (*Lunuloceras*) *fallax* Zeiss., *L. (Sublunuloceras)* cf. *dynastes* (Waag.), *L. (S.) spathi* Djan., *Putealicerias* (*Putealicerias*) cf. *bisulcatum* (Spath), *P. (Zieteniceras)* cf. *couffoni* (Douv.), *Passendorferia* (*Passendorferia*) *chirchonensis* (Djan.),

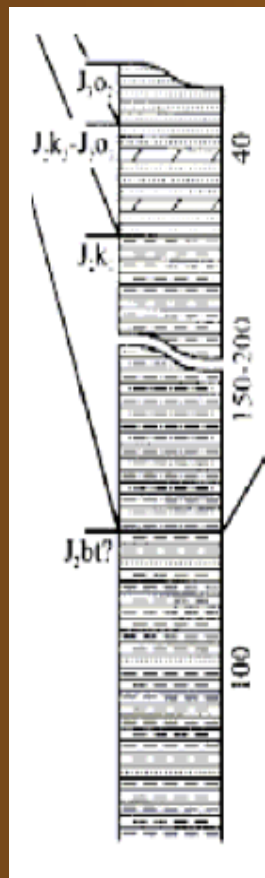
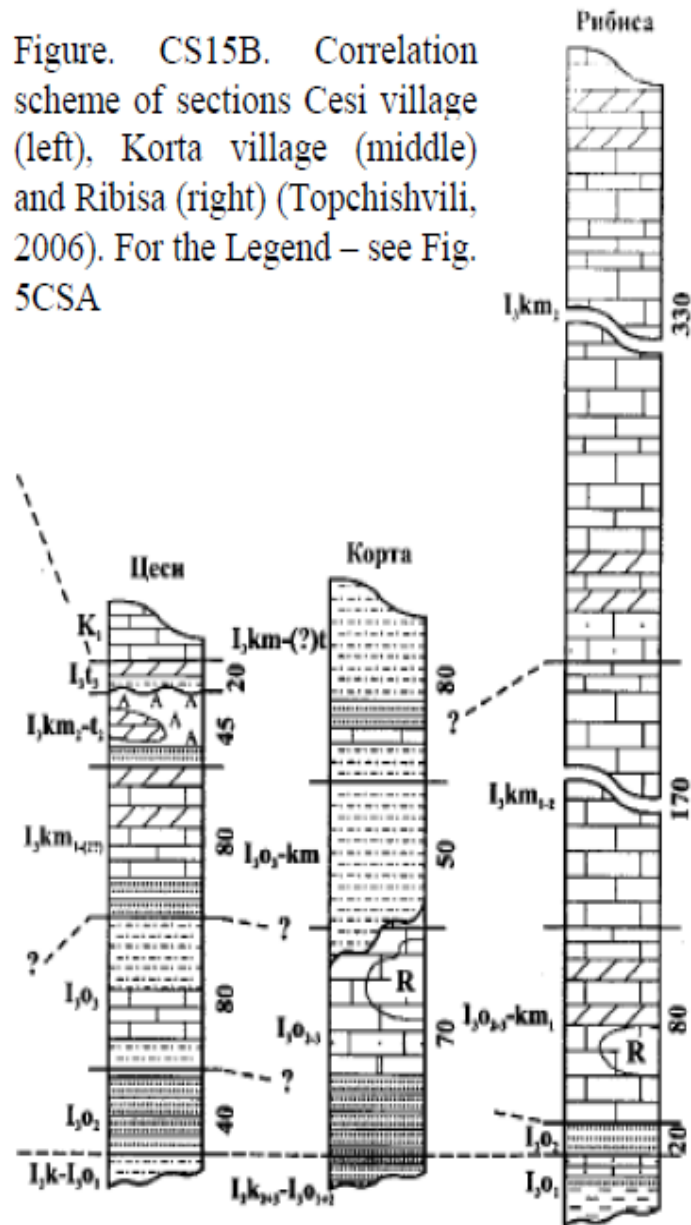


Figure CS15A. Section near Korta village (Topchishvili, 2006). For the Legend – see Fig. 5CSA

Figure. CS15B. Correlation scheme of sections Cesi village (left), Korta village (middle) and Ribisa (right) (Topchishvili, 2006). For the Legend – see Fig. 5CSA



Distichoceras bipartitum (Ziet.), *Larcheria ex gr. schilli* (Opp.), *Properisphictes cf. bernensis* (Lor.), *Euaspidoceras hirsutum* (Bayle), *E. aff. babeanum* (d'Orb.), *E. ferrugineus* Jeann., *E. faustum* (Bayle), *E. cf. perarmatum* (Sow.), and also foraminifers and dinoflagellates: *Ctenidodinium ornatum* Defl.,

Sentusidinium rioultii Sarj. et Stov., *S. sp.* Thus, “Korta beds” contain J_2k_{2-3} — J_3o_{1-2} fossils.

Member 3. J_3o_{2-3} Breccia-like carbonate sandstones and sandy limestones (20–25 m).

Member 4. J_3o_{2-3} Carbonate sandstones and hard dolomites with rudists (*Diceras* sp.). Thickness 30 m.

Member 5. J_3o_{2-3} Bedded sandy limestones with corals, crinoids and sea urchins (11–15 m).

Member 6. J_3o_3 —km Massive brecciated reef limestones (50 m). Members 3–5 contains Middle and Upper Oxfordian

foraminifers: *Astacolus cf. lusidisepta* (Kapt.), *A. cf. varians* (Born.), *Lenticulina cf. brueckmanni* (Mjatl.), *L. cf. tumida* Mjatl., *L. cf. erassa* (Roem.), *L. cf. polonica* (Wisn.), *L. cf. uhligi* (Wisn.), *Planularia cf. colligata* (Brueckm.), “*Ceratolamarckina*” cf. *subspeciosa* (Bogd. et Mak.),

Trocholina cf. transversarii Paalz. Member 5 is characterized by Middle and

Late Oxfordian corals: *Montlivaltia elongata* Edw., *M. truncata* (Def.), and also *Astarte nummus* Sauv., *Ostrea ogeriana* Lor. And Late Oxfordian *Paracidaris florigemma* Phill., *Rabdocidaris orbinyi* Des., *Diplocidaris gigantes* Ag., *Plagiocidaris elegans* Goldf. Member 6 contains rich Late Oxfordian and Kimmeridgian coral complex: *Dimorpharaea lineata* (Eichw.), *Calamophyllopius etalloni* Koby, *C. flabellum* (Mich.), *Isastraea helianthoides* (Goldf.), *I. minima* (Koby), *Stylina tubulifera* Phil., *S. tenax* Etall, *Heliocoenia aff. costulata* Koby (Topchishvili et al., 2006).

Upper Oxfordian coincides to beds with *Alveosepta jaccardi* — *Nautiloculina ootithica* (= zone *Haplophragmium coprolilhiiforme sequanum* — *Nautiloculina oolithica* = zone *Alveosepta jaccardi* — *Epistomina nemunensis*).

Lectostratotype — reef brecciated limestones (thickness – 40 m according to Practice..., 1991). Foraminiferal complex in the stratotype: *Alveosepta jaccardi* (Schrodt), *Everticyclammina virguliana* (Koechl.), *Haplophragmium coprolithiforme sequanum* (Moh1.), *Nautiloculina oolithica* Moh1., *Lenticulina russiensis* (Mjatl.), “*Ceratolamarckina*” *subspeciosa* (Bogd. et Mak.), *Epistomina nemunensis* Grig., *Conicospirillina basiliensis* Mohl., *C. polessica* Mitjan., *Spirillina kuebleri* Mjatl., *Trocholina transversarii* Paalz. Foraminifers are rare. Discovered 30 species (15 genus), mainly Lituolids and Ataxofragmiids, to lesser extent — Miliolids and Nodosariids. Typical species: *Alveosepta jaccardi*, *Everticyclammina virguliana*, *Haplophragmium coprolithiforme sequanum*, *Nautiloculina oolithica*.

Lower boundary of beds is detected by appearance of *Everticyclammina virguliana*, *Nautiloculina oolithica*, *Conicospirillina basiliensis* and epibol *Alveosepta jaccardi*; upper — by disappearance of “*Ceratolamarckina*” *subspeciosa* and some others.

Middle Oxfordian–Tithonian in Racha area (validation points no. 15–17) coincides to Lukhunskaya Fm. (Topchishvili et al., 2006)

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within the Tkvarcheli-Okrib(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data

Member 2. J₂k₁. Brown carbonate sandstones and greenish clays with *Hecticoceras* (*Hecticoceras*) *hecticum* (Pratt.). Visual thickness – 4 m.

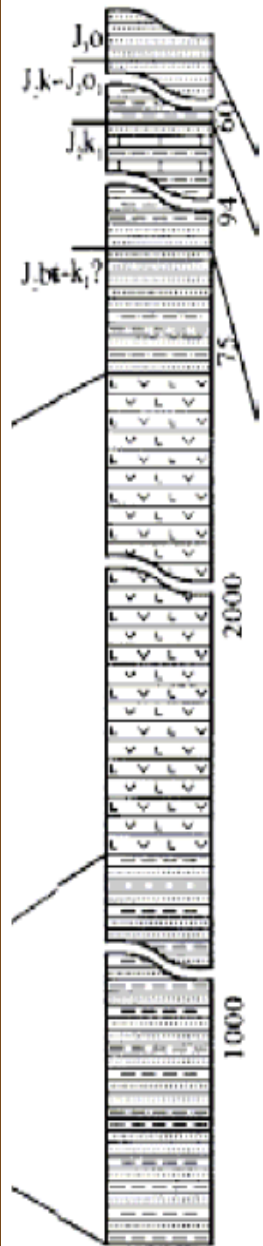


Figure CS16A. Section 1 near Cesi village (Topchishvili, 2006). For the Legend – see Fig. 5CSA

Member 3. J_2k_1 . Alternation of gray shale-like clays and clayey sandstones with thin beds of sandy limestones with *Macrocephalites formosus* (Sow.), *M. canizarroi* (Gemm.), *M. cf. rotundus* (Quenst.), *M. madagascariensis* Lem., *M. compressus* (Quenst.), *Pleurocephalites tumidus* (Rein.), *Kamptokephalites lamellosus* (Sow.), *K. colchicus* (Djan.), *K. subtrapezinus* (Waag.), *Indocephalites cf. chrysolithicus* (Waag.), *I. caucasicus* (Djan.), *Dolikephalites subcompressus* (Waag.), *Cadoceras (Cadoceras) elatmae* (Nik.), *C. (C.) modiolare* (d'Orb.), *Choffatia (Choffatia) radshense* (Djan.), *C.(C.) frequens* (Opp.), *C.(Grossouvria) subtilis* (Neum.), *C.(G.) evolutus* (Neum.), *C.(Subgrossouvria) tsessiense* (Djan.), *C. (S.) recuperoi* (Gemm.), *Indosphinctes (Indosphinctes) pseudopatina* (Par. et Bonar.), *I (I.) choffati* (Par. et Bonar.), *I (I.) cf. peregrinus* Spath, *Flabellisphinctes (Flabellia) kakhadzei* Khim., *Hecticoceras (Hecticoceras) hecticum* (Prat.), *Kepplerites (Kepplerites) kepleri* (Opp.), *K.(Gowericeras) gowerianus* (Sow.), *Lissoceras minimum* Djan., *Adabofoloceras faddenii* (Waag.), *Hibolites semihastatus* (Blain.) and others. Dinoflagellates: *Cleistosphaeridium varispinosum* Wool, et Rid., *Compositosphaeridium polonicum* Erk. et Sarj., *Valensiella ovula* Eisen., *Pareodinia cearatophora* Delf., *Meiourogonyaulax* sp., *Chytroeisphaeridia chytroeides* Dow. et Arj. Thickness – 60 m.

Member 4. J_2k_{1-3} - J_3o_1 Brown carbonate and sandy clays transiting into gray clayey sandstones. At the lower part of the member *Homoeoplanulites (Parachoffatia) funatus* (Opp.), *Choffatia (Choffatia) prorsocostata* (Siem.), *Adabofoloceras viator* (d'Orb.) were found. Above typical for Middle Callovian forms *Lunuloceras (Lunuloceras) compresus* (Quenst.), *L. (L.) pavlovi* (Tsyt.), *Putealicerias (Putealicerias) metomphalum* (Bonar.) were met. At the top of the member Late Callovian–Early Oxfordian *Lunuloceras (Sublunuloceras) georgica* Khim and also Oxfordian *Trigonia perculata* Ag., *T. clavellaculata* Park., *T. reticulata* Ag., *Pholadomya lineata* Goldf., *Astarte ovata* Phill., *Lucina lirata* Phill., *Mytilus unguulatus* Young et Bird and others occurred. Thickness is 60 m (Toptishvili et al., 2006).

Next part of the sequence is exposed at another place (Section 2).

In the middle of Cesi settlement along the highway and also to the SE along right bank of Rioni river (Section 2, Fig CS15B) greenish-gray thin-bedded soft carbonate sandstones (30 m, upper part coincides to Lower Oxfordian) are overlaid by following section (Toptishvili et al., 2006):

Member 1. J_3o_2 Yellowish-brown medium- and coarse-grained carbonate sandstones (35–40 m) with Oxfordian corals: *Cryptocoenia bernensis* (Etall.), *C. cartieri* Koby, *Latimeandra goldfussi* Koby, *Montlivaltia subdispear* From. Here middle Oxfordian foraminifers: *Labalina microcostata* Dan., *Astacolus folium* (Wisn.), *Lenticulina compressaeformis* (Paalz.), *Planuraia feifeli* Paalz., *Vaginulina pasquetae* Biz., "*Ceratolamarckina*" *subspeciosa* (Bogd. et Mak.), *Trocholina transversarii* Paalz. occur. Then – 10–15 m of unexposed part.

Member 2. J₃O₃ Weakly colored carbonate sandy clays with thin beds, lenses and concretions of organogenous limestones with plant remnants (75–80 m) and Late Oxfordian foraminifers *Lenticulina gerassimovi* Umansk., *L. russiensis* (Mjatl.), *Epistomina nemunensis* Grig., *E. praetatarsiensis* Umansk. and others (Toptishvili et al., 2006). These deposits coinciding to beds with *Lenticulina russiensis* – *Epistomina nemunensis* present part of the poly-colored Fm. formed in the back-reef basin (Practice..., 1991).

Foraminiferal complex in the stratotype (**Member 2.** J₃O₃): *Lenticulina brueckmanni* (Mja1.), *L. gerassimovi* Umansk., *L. kuznetsovae* Umansk., *L. polonica polonica* (Wisn.), *L. quenstedti* (Gtimb.), *L. russiensis* (Mja1.), *Saracenaria* aff. *pravoslavlevi* Furss. et Pol., *S. prolata* K-Kuzn., *Epistomina nemunensis* Grig., *E. parastelligera* (Hofk.), *E. praelatarsiensis* (Umansk.), *E. stellcostata* Biel. et Pozar., *E. uhligi* Mja1., *Pseudoamarckina pseudorjasanensis* Dain and others. Many shells of foraminifers. 30 species (9 genus) were found.

Typical species: *Lenticulina gerassimovi*, *L. kuznetsovae*, *L. russiensis*, *Epistomina nemunensis*, *E. praetatarsiensis*.

Lower boundary of beds coincides to appearance of typical species, upper — by disappearance of *Epistomina nemunensis*, *E. uhligi*, *Conicospirillina polessica*, *Planularia alberti*. Association is renewed more than in 1/3 part (38 %) in comparison with Middle Oxfordian one.

In the stratotype area also were found: *Astacolus suprajurassicus* (Schwag.), *Lenticulina crassa* (Roem.), *L. subgaleata* (Wisn.), *Planularia alberti* (Schwag.), *Saracenaria cornucopiae* (Schwag.), *Trocholina nodulosa* Seib., *Conicospirillina polessica* Mitjan. and others (Practice..., 1991).

Next part of the sequence is exposed at another place (Section 3).

Section 3. Vicinity of Cesi and Mukhli (42.32.54.02 N, 43.14.03.47 E, determined by Google Earth) villages (Practice..., 1991, Fig. CS15B).

Member 1. J₃km–tt₁ Poly-colored gypsum and anhydrites with thin beds of gypsum-bearing clays (upper part of lagoon-continental polycolored Fm.) coincides to beds with *Charentia compressa* — *Mesoendothyra* sp. (= beds with *Guttulina dogieli*; = beds with *Lituola compressa* — *Trocholina elongata*). Thickness – 45 m.

Foraminiferal complex in the stratotype: *Charentia compressa* (Cushman et G1az.), *Mesoendothyra* sp., *Trochammina* cf. *inflata* Mont., *Eoguttulina* cf. *metensis* (Terq.), *E.* cf. *oolithica* (Terq.), *Globulina* sp., non determined Miliolids and others. Foraminifers are sporadically distributed and badly preserved. Typical species: *Charentia compressa*, *Mesoendothyra* sp.

Member 2. J₃tt₂₋₃ At the left bank of Rioni river within Cesi village greenish-gray sandy limestones, alternation of brownish sandstones, dark-gray sandy clays, sandy-marly and dolomitized limestones, pinkish clayey marls, light gray sandy, marly and dolomitized limestones (upper part of lagoon-continental poly-colored Fm.) coinciding to beds with *Feurtillia frequens*—*Trocholina elongata* (= beds with *Feurtillia frequens*—*Pseudocydammina parvula*; beds with *Quinqueloculina mitchurini* and *Pseudocydammina parvula* = beds with *Quinqueloculina verbizhiensis* and *Trocholina elongata* are exposed. Thickness – 20 m.

Foraminiferal complex in the typical section: *Feurtillia frequens* Maync, *Pseudocyclammina parvula* Hott., *P. sulaiyana* Redm., *Everticyclammina virguliana* (Koechl.), *Pfenderina* “*neocomiensis*” (Pfend.), *Lenticulina muensteri* (Roem.), *Epistomina caracolla* (Roem.). Foraminifers locally make a big accumulations. Lituolids comprise 98 % of association.

Typical species: *Anchispirocyclus lusitanica*, *A. maynci*, *Everticyclammina virguliana*, *Feurtillia frequens*, *Pseudocyclammina parvula*, *Trocholina alpina*, *T. elongata*.

Lower boundary of beds is detected by appearance of *Bramkampella arabica*, *Feurtillia frequens*, *Melathrokerion spirialis*, *Pseudocyclammina sulaiyana*, upper — by disappearance *Anchispirocyclus maynci*, *Pseudocyclammina ex gr. parvulamuluchensis*, *Rectocyclammina arrabi-densis*. In the stratotypic region association is renewed up to 1/3 in comparison with Kimmeridgian – Lower Tithonian.

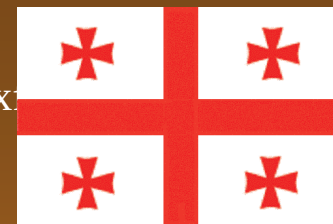
Within area of distribution of these beds the following association is determined: species from stratotype, *Anchispirocyclus lusitanica* (Egg.), *A. maynci* (Hott.), *Bramkampella arabica* Redm., *Melathrokerion spirialis* Gorb., *Pseudocyclammina ex gr. parvula-muluchensis* Hott., *Rectocyclammina arrabidensis* Ram., *R. chouberti* Hott., *Lenticulina makarjevae* E. Ivan., *Trocholina alpina* (Leup.), *T. elongata* (Leup.).

Interpretation - Shallow-marine and lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Tkvarcheli-Okrib(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data



Locality 17: Northern slope of Ribisa Mt., Ambrolauri region, Georgia

Position (approximately determined by Google Earth): 42.45. N, 41.30. E **Age:** Oxfordian–Kimmeridgian

Sedimentology:

Description – At the Northern slope of Ribisa Mt. (2469 m). Callovian clayey sandstones and sandy clays are overlaid by following sequence (Toptishvili et al., 2006, Fig. CS15B).

Member 1. J₃O₁ Fine grained greenish gray carbonate sandstones with ammonite *Neoprionoceras delmontanus* (Opp.) from cordatum zone. At the top – of brownish-violet colour. Thickness – 15–18 m.

Member 2. J₃O₂ Dark gray thin bedded weakly dolomitized limestones with Mid-Oxfordian genus *Everticyclammina* Redm., appeared at Mid-Oxfordian time (18–22 m).

Member 3. J₃O₂₋₃–km₁ Light gray thin-bedded massive limestones with marl beds, in the lower part with sandy limestones (75–80 m). At the lower part of this member but near Djavistavi village ammonites *Taramelliceras* aff. *flexuosus* (Munst.) and *Euaspidoceras* cf. *eucyphus* (Opp.) of Middle Oxfordian transversarium zone were met. Above this level Late Oxfordian corals (Djavistavi section) *Stylosmilia michelini* Edw. et Haime, *Stylina sexradiata* (Goldf.), *Cryptocoenia decipiens* (Etall.), *Ptychochaetetes globosus* Koechl. And at the top of member Kimmeridgian *Stylosmilia suevica* Beck., *Stylina sexradiata* (Goldf.), *Diplocoenia coespitosa* (Etal.), *Calamophylliopsis etalloni* (Koby) occurred.

Member 4. J₃km₁₋₂ Alternation of thick- and thin-bedded marly limestones with rich Kimmeridgian ammonite fauna: *Calliphyloceras praeposterius* (Gemm.), *C.* aff. *benecke*i (Zitt.), *Lytoceras orsinii* (Gemm.), *Streblites* cf. *frotho* (Opp.), *Idoceras allobrogicus* (Pillet.), *I. malletianus* (Font.), *I. balderum* (Opp.), *I.* cf. *durangense* (Burckh.), *Taramelliceras* cf. *holbeini* (Opp.), *T.* cf. *rigidum* (Wegele), *Nebrodit*es *hospes* (Neum.), *N. heimi* (Favre), *N. rhodanensis* Ziegl., *Progeronia* sp., *Orthosphinctes* cf. *polygyratus* (Rein.) and others. Here also foraminifers *Alveosepta jaccardi* (Schr.), *A. personata* (Tobl.), *Mesoendothyra* cf. *izjumiana* Dain, *Pseudocyclammia lituus* (Yok.), *Haplophragmium coprolithiformis sequanum* Mohl., *H.* cf. *lutzei* Hanzl., *Quenqueloculina* cf. *semisphaeroidalis* Dan., *Q.* cf. *tersa* Dan. are met. Thickness – 160–170 m (Topchishvili et al., 2006).

Lower Kimmeridgian corresponds to *Alveosepta personata* — *Torinosuella peneropliformis* zone that is presented by reef brecciated limestone and marl unit (490 m thick) (Practice., 1991). Possibly authors (Practice., 1991) mean whole section (members 3–8? according to Topchishvili et al., 2006 – *comm. R.R. Gabdullin*).

Foraminiferal complex in the stratotype: *Alveosepta jaccardi* (Schrodt), *A. personata* (Tob1.), *Everticyclammina virguliana* (Koschl.), *Mesoendothyra izjumiana* Dain, *Pseudocyclammina lituus* (Yok.), *Haplophragmium coprolithiforme sequanum* (Mohl.), *H. lutzei* Hanzl., *Kurnubia palastiniensis* Hens., *Pfenderina "neocomiensis"* (Pfend.), *Nautilloculina oolithica* Mohl., *Quinqueloculina semisphaeroidalis* Dan., *Lenticulina russiensis* (Mjatl.), *L. subalata* (Reuss), *Conicospirillina basiliensis* Mohl., *Trocholina elongata* (Leup.), *Protopeneroplis striata* Weynsch. Usually foraminifers are rarely distributed along the section but sometimes make mass groups. The quantity of agglutinated benthos is 85 % (Lituolids prevail), secretional is presented mainly by Lenticulinids, Fisherinids, Miliolids and Spirillinids.

Typical species: *Alveosepta jaccardi*, *A. personata*, *Mesoendothyra izjumiana*, *Pseudocyclammina lituus*, *Torinosuella peneropliformis*, *Nautilloculina oolithica*, *Conicospirillina basiliensis*.

Lower boundary of beds is detected by appearance of *Alveosepta personata*, *Pseudocyclammina sphaeroidalis*, *Torinosuella peneropliformis* and row of some other species; at upper boundary index species *Alveosepta jaccardi*, *Haplophragmium coprolithiforme sequanum* and some others disappear. In the stratotypic region association of described zone is renewed in comparison with Upper Oxfordian up to 60 %.

Within zone in stratotype *Haplophragmoides constrictum* (Haeus1.), *Pseudocyclammina sphaeroidalis* Ho11., *Torinosuella peneropliformis* (Yabe et Hanz.), *Labirynthina mirabilis* Weynsch., *Trochammina rotunda* E. et I. Seib., *Verneuilinoides minuta* Said et Barak., *Lenticulina crassa* (Roem.), *L. infravolgaensis* (Furss. et Pol.), *L. quenstedli* (Guemb.), *Trocholina alpina* (Leup.), *T. transversarii* Paa1z. are distributed (Practice., 1991).

Member 5. J₃km₂ Thick-bedded oolitic sandy limestones with *Conicospirillina basiliensis* Mohl., *Protopeneroplis* cf. *striata* (Weyn.) and others. Thickness – 15– 20 m.

Member 6. J₃km₂ Light gray thin-bedded marls with rare thin beds of hard carbonate sandstones with *Rhactorhynchia corallina neocomiensis* (Jac. Et Fall.) and also foraminifers *Alveosepta jaccardi* (Schr.), *Astacolus humilatus* Putr., *Lenticulina russiensis* (Mjatl.), *L. posttumida* Dain. At the base ammonites *Paraberriasella* cf. *blondeti* Donze and *P. sp.* were found. Thickness – 40–45 m.

Member 6. J₃km₂ Dark gray on the surface brown thick-bedded oolitic limestones with foraminifers: *Alveosepta* cf. *jaccardi* (Schr.), *Everticyclammina* cf. *virguliana* (Koechl.), *Mesoendothyra* cf. *izjumiana* Dain, *Pseudocyclammina* cf. *lituus* (Yok.), *Nautilloculina* cf. *oolithica* Mohl., *Conicospi rillina* cf. *basiliensis* Mohl., *Trocholina* cf. *elongata* (Leup.), *Protopeneroplis* cf. *striata* Weyn. Thickness – 50–60 m.

Member 7. J₃km₂ Dark gray marly brecciated limestones rich in foraminifers: *Alveosepta jaccardi* (Schr.), *A. personata* (Tobl.), *A. powersi* (Redm.), *Evenicyclammina virguliana* (Koechl.), *Pseudocyclammina* cf. *lituus* (Yok.), *Urgonina* cf. *forojuliensis* Guv., Foury et Pign., *Protopeneroplis* cf. *striata* Weyn. Thickness – 120 m (Toptishvili et al., 2006).

Section is continued near **Alkhashend mountain pass**.

Member 8. J₃km₂ Violet marly limestones and marls with abundant thin beds of light gray marls. At basal beds foraminifers *Alveosepta jaccardi* (Schr.), *A. personata* (Tobl.), *Pseudocyclammina lituus* (Yok.) were found. Thickness – 75–80 m (Topchishvili et al., 2006).

Interpretation - Shallow-marine, probably lagoon(?) environment.

Structure: No data.

Regional significance: This validation point is located within the Tkvarcheli-Okrib(skaya) zone (see Fig. 3.5)

Petroleum systems information: No data



Locality 18: Kalakend Village, Kedabeg region, Azerbaijan

Position (of Kedabeg region centre determined by Google Earth): 40.33.51.94 N, 45.47.21.54 E

Age: Callovian–Middle Oxfordian, Lower Kimmeridgian, Upper Tithonian

Sedimentology:

Description (Abdulkasumzade, 1988) – Kedabeg(skaya) Fm. (Callovian–Lower Oxfordian) coincides to Members 1–3.

Member 1. J_2k_1 Tuff sandstones, carbonate tuffs, tuff conglomerates, siltstones, argillites (161 m). No determinable fossils.

Member 2. J_2k_2 Carbonate tuffites, conglomerates, argillites, gravelites (175 m) with *Holcophylloceras signodianum* (Orb.), *Ptychophylloceras* cf. *hommarei* (Orb.), *Putealicerias* (P.) *metomphalum* (Bon.), *P. (P.) punctatum punctatum* (Stahl.), *Grossouvria curvicosta* (Opp.), *Lunuloceras* (L.) *lunula* (Rein.)

Member 3. J_2k_3 Tuff sandstones, red carbonate tuffites with *Pseudaganites* cf. *aganiticus* (Schloth.), *P. aff. gravesianum* (Orb.), *Holcophylloceras mediterraneum* (Neum.), *Sowerbyceras protortisulcatum* (Pomp.), *Sow. tietzei* Till., *Pseudophylloceras kunthi* (Neum.), *Oecoptychius refractus* (Rein.), *Lunuloceras (Sublunuloceras) dynastes* (Waag.), *Peltoceras* (P.) *athleta* (Phill.), *Peltoceratoides athletoides* (Lah.) (2 m)
Upper Callovian rocks with erosion are covered by Middle Oxfordian deposits of Kalakend(skaya) Fm (Members 4–6).

Member 4. $J_2o_2^1$ Fine grained reddish brown basal conglomerate with pebbles of cherty limestones, sandy limestones, tuff sandstones cemented by carbonate tuffite and carbonate (2 m).

Member 5. $J_2o_2^1$ Organogenous-clastic, sandy, marbleized, pelitomorphic white limestones with *Perisphinctes plicatilis* (Sow.), *Euaspidoceras* (E.) *perarmatum* (Sow.), *Calliphylloceras manfredi* (Opp.), *Sowerbyceras tortisulcatum* (Orb.), *Montlivaltia trunoata* D., *Rhipidogyra elegans* Koby, *Stylosmilia michelini* Edw. et. H. (20 m).

Member 6. $J_2o_2^2$ Organogenous-clastic, sandy, marbleized, coralline white limestones with *Gregoryceras transversarium* (Quenst.), *Ochetoceras canaliculatum* (Buch.) and coral limestones with *Cryptocoenia octosepta* Etall., *Calomophylloids flabellum* M. (60 m)

Within Kalakend syncline Oxfordian and Lower Kimmeridgian carbonate and sedimentary-tuff units are 220 m thick. At Dashkesan region Upper Oxfordian rocks are conformably overlaid by Lower Kimmeridgian ones.

In a narrow stripe near the village Lower Kimmeridgian deposits are exposed.

Member 7. J₂km₁ Organogenous-clastic bedded reddish-brown, gravelite-like limestones with 12 thin beds of brecciated limestones (0.2–2 m) with *Taramelliceras* (Str.) *externodosum* (Dorn.), *Streblites plicodiscus* (Waag.), *Sutneria platynota* (Rein.), *S. (S.) brachiri* Berck., *Ataxioceras* (P.) *pseudohomalinum* Geuer, *Physodoceras inflatus macrocephalus* (Quenst.). 40 m.

Upper Kimmeridgian span of sequence can be observed at the next field validation point (No. 19, G(K)onakhgermaz Mt.)

In Kedabeg region near Kalakend and Arysuvillages Tithonian deposits (42 m) conformably cover Upper Kimmeridgian and are presented by light-gray thin bedded organogenous-clastic and gravelite-like, cherty limestones of Martuninskaya Fm. (Members 8–13). At Kalakend area following section of Upper Tithonian is exposed.

Member 8. J₃tt₂ Light-gray basal conglomerates with pebble of cherty limestones and carbonate sandstones with *Physodoceras inflatus macrocephalus* (Quenst.), *Taramelliceras* (Str.) *externodosum* (Dorn.) (1.5–2 m).

Member 9. J₃tt₂ Alternation of clastic limestones with thin beds of conglomerates that facially transform into gravelites (10.4 m). At the base gastropod *Cryptoplocus succedens* (Zitt.) was found.

Member 10. J₃tt₂ Light-gray medium-bedded cherty, sometimes clastic limestones with colonial corals *Cyatophora baurgueti* (Defr.), *Calamophyllia etalloni* Koby, *Thecosmilia* cf. *virgulina* (Etall.). 7 m.

Member 11. J₃tt₂ Pinkish limestones alternated with gravelite-like limestones transforming into clastic ones (11 m).

Member 12. J₃tt₂ Alternation of gray and pinkish clastic medium-bedded cherty limestones (10 m).

Member 13. J₃tt₂ Alternation of light-gray sandy and cherty limestones with *Sphaeractinia diceratina* (Stein.). 2 m.

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within the Khram(skaya) subzone of Somkheto-Karabakh zone(see Fig. 3.5)

Petroleum systems information: No data



Locality 19: G(K)onakhgermaz Mt., Khachbulag Village, Dashkesan region, Azerbaijan

Position (of Dashkesan region centre determined by Google Earth): 40.31.05.27 N, 46.04.57.45 E

Age: Upper Kimmeridgian

Sedimentology:

Description (Abdulkasumzade, 1988) – Upper Kimmeridgian deposits are developed in the core of Dashkesan syncline. The most complete section of 450 m thick is exposed at the Southern slope of Gonakhgermaz Mt. Upper Kimmeridgian have uncorformity at the base with Oxfordian and at the top with Tithonian. Absolute age of volcanic unit is 140 ma.

Member 1. J₃km₂ Coarse-grained tuff conglomerates. Clasts (fragments) consist of limestones (lower part) and porphyrites (upper part). 20 m.

Member 2. J₃km₂ Andesite porphyrites (20 m).

Member 3. J₃km₂ Alternation of coarse- and fine-grained tuff conglomerates (110 m).

Member 4. J₃km₂ Dark gray–black andesite and basalt porphyrites (300 m).

Tithonian deposits within Dashkesan area are locally distributed.

Interpretation - Shallow-marine environment.

Structure: No data

Regional significance: This validation point is located within the Khram(skaya) subzone of Somkheto-Karabakh zone(see Fig. 3.5)

Petroleum systems information: No data

Field trip. Validation points

CS20

Locality 20: Baksan River, NE Caucasus, Tyrnayz region (near Elbrus Mt.), Russia

Position (determined by Google Earth): 43.26.00.00 N, 43.10.00.00 E

Age: Upper Kimmeridgian (?) – Upper Tithonian



Sedimentology:

Description (Sakharov, 1983) – Section of Upper Kimmeridgian (?) – Valanginian deposits is exposed along Baksan River (Fig. CS20A)

Member 1. J₃km₂(?)–tt₂(?). Upper Kimmeridgian (?) – Middle Tithonian (?) white and light gray massive gypsum and anhydrites with thin beds of brownish-gray dolomites. 130 m.

Member 2 transgressively cover previous member. J₃tt₃. Gray organogenous-clastic limestones with finds of oysters, brachiopods and worms (*Serpula coacervata* Blum.). Thickness – 5 m.

Member 3 J₃tt₃. Gray fine-grained bedded limestones with carbonate concretions up to 0.2 m in diameter oriented conformably to bedding. At the lower part find of *Virgatospinctes* sp. Thickness 47 m.

Member 4 J₃tt₃. Gray clayey silty limestones. Thickness 54 m.

Member 5 J₃tt₃. Unit of rhythmic alternation of gray fine-grained medium-bedded enriched in terrigenous material limestones with cherty-carbonate bed-like concretions with bivalves in the middle. Thickness 44 m.

Member 6 J₃tt₃. Algael gray massive clayey limestones with *Myophorella suevica* Quenst. Thickness – 13 m.

Member 7 J₃tt₃. Dark gray medium-bedded limestones with concretions of cherty limestones. Within last big oysters and fragments of *Virgatospinctes* sp. occur. To the upper half of the member finds of *Tithopeltoceras nescium* Sach., sp. nov,

Buchia sp., *Pinna* cf. *suprajurensis* Orb., *Gervillia linearis* Buv., *G. gottschei* Boehm, *Exogyra baksaensis* Pchel., *Amphidonta bruntruncana* Thurm., *Trigonia siliceum* Quenst., *Myophorella suevica* Quenst., *Cyprina brongniarty* Roem., *C.cf. abkhasica* Khim., *Cardium bernuilense* Lor., *Thracia incerta* Thurm., *Nearea caucasica* Pchel., *Serpula coacervata* Blum. Thickness 30 m.

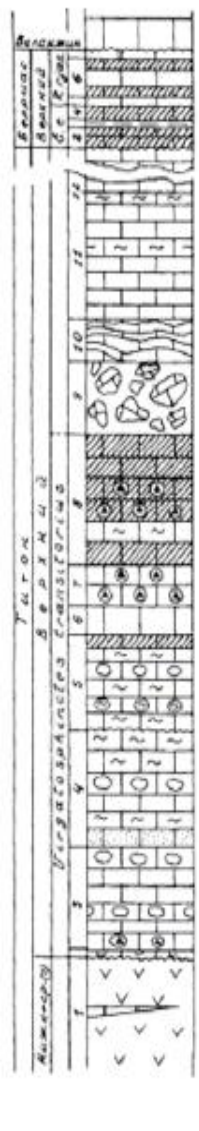


Figure CS20A. Section along Baksan River (Sakharov, 1983). Legend – see next Fig.

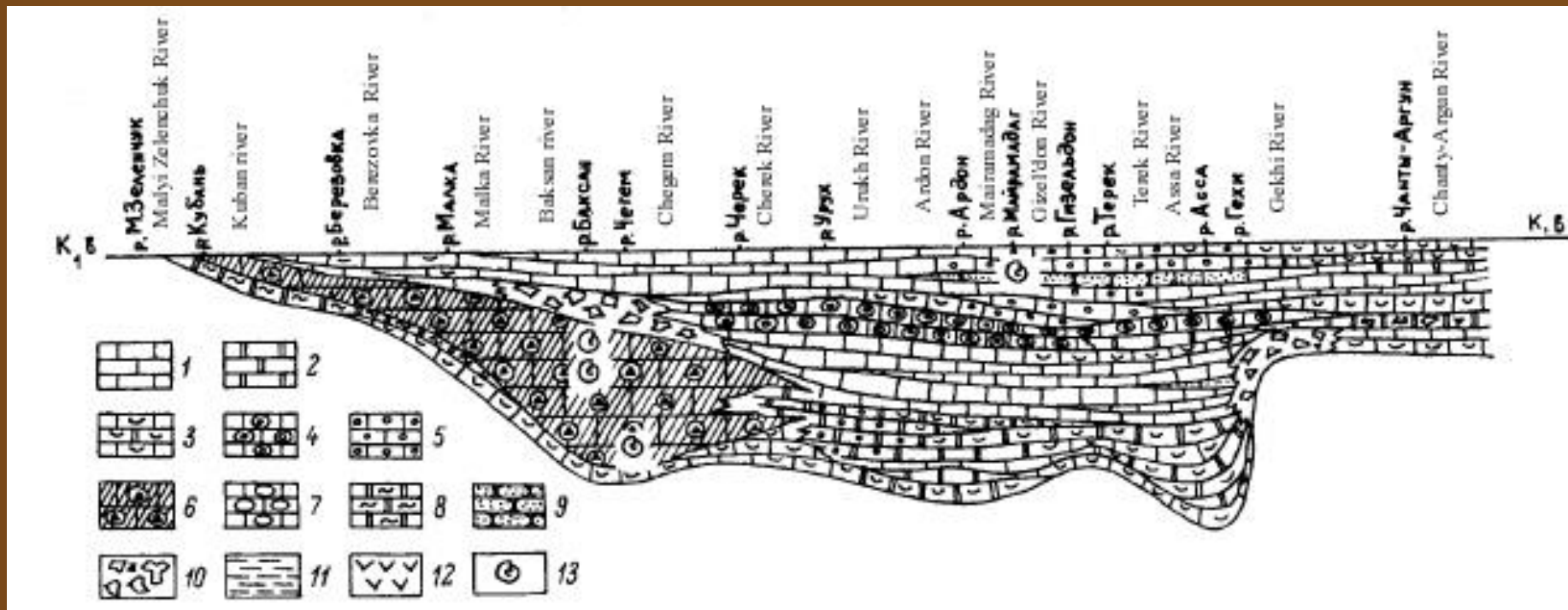


Figure CS20B (Sakharov, 1983). Composition of Upper Tithonian of Kuban'-Terek interfluvium: 1 – limestones, 2 – dolomites, 3 – organogenous-clastic limestones and dolomites, 4 – oolitic limestones, 5 – calcarenites, 6 – clayey limestones with pale light brown concretions, 7 – pale light brown limestones, 8 – silty dolomites, 9 – sandtones, 10 – breccias, 11 – clays, 12 – gypsum and anhydrites, 13 – ammonites

Member 8 J₃tt₃. Bluish-gray clayey fine-grained massive limestones with innumerable concretions of cherty limestones with fragments of *Virgatospinctes* cf. *transitorius* Opp., *Serpula coacervata* Blum. colonies. Thickness – 60 m.

Member 9 J₃tt₃. Breccia consisting of fragments of pale light brown and pink fine-grained limestones. Thickness – 35 m.

Member 10 J₃tt₃. Gray-light brown fine-grained wave-thin-bedded limestones. Thickness – 20 m.

Member 11 J₃tt₃. Alternation of fine-grained limestones with thin-bedded silty limestones. Thickness – 60 m.

Member 12 J₃tt₃. Alternation of light gray and gray thinly bedded and leaf-like detrital and radiolarian with clayey thinly bedded limestones with radiolaria: *Cenospharca* sp., *Coneclipsis* sp., *Hemicryptocapsa* sp., *Stichocapsa* sp.

Member 12 is exposed in the narrow transversal gorge connected with Baksan River. Here Jurassic-Cretaceous boundary and also Berriasian-Valanginian sequence is exposed. Lower Tithonian rocks with erosion are covered by upper Berriasian deposits. Facial profile is given on Fig. CS20B.

Interpretation - Shallow-marine and lagoon environment.

Structure: No data

Regional significance: This validation point is located within the Kabarda-Dagestan(skaya) zone (see Fig 3.5)

Petroleum systems information: No data

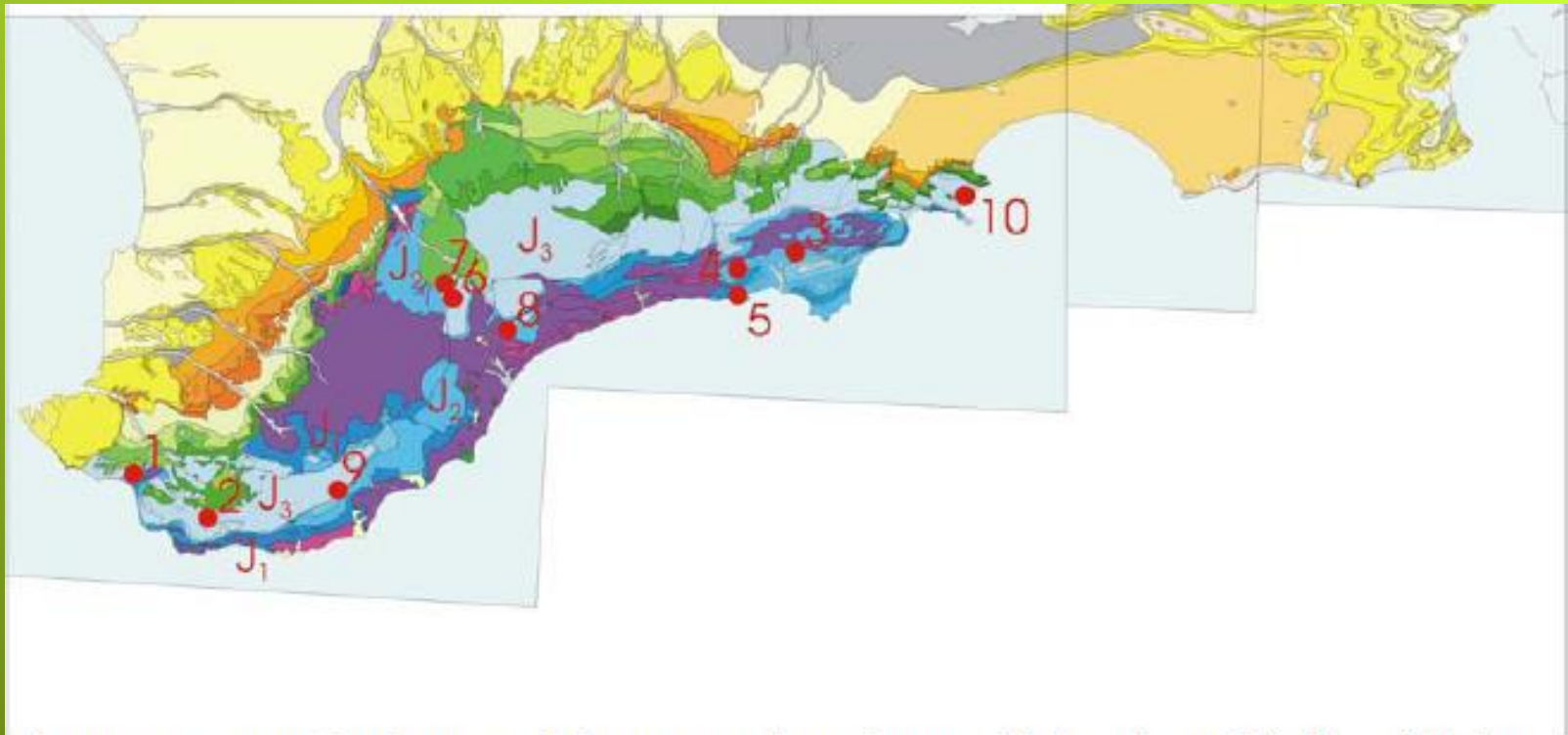


Figure 2.2.6. Geologic map of the Mountain Crimea with location of field validation points

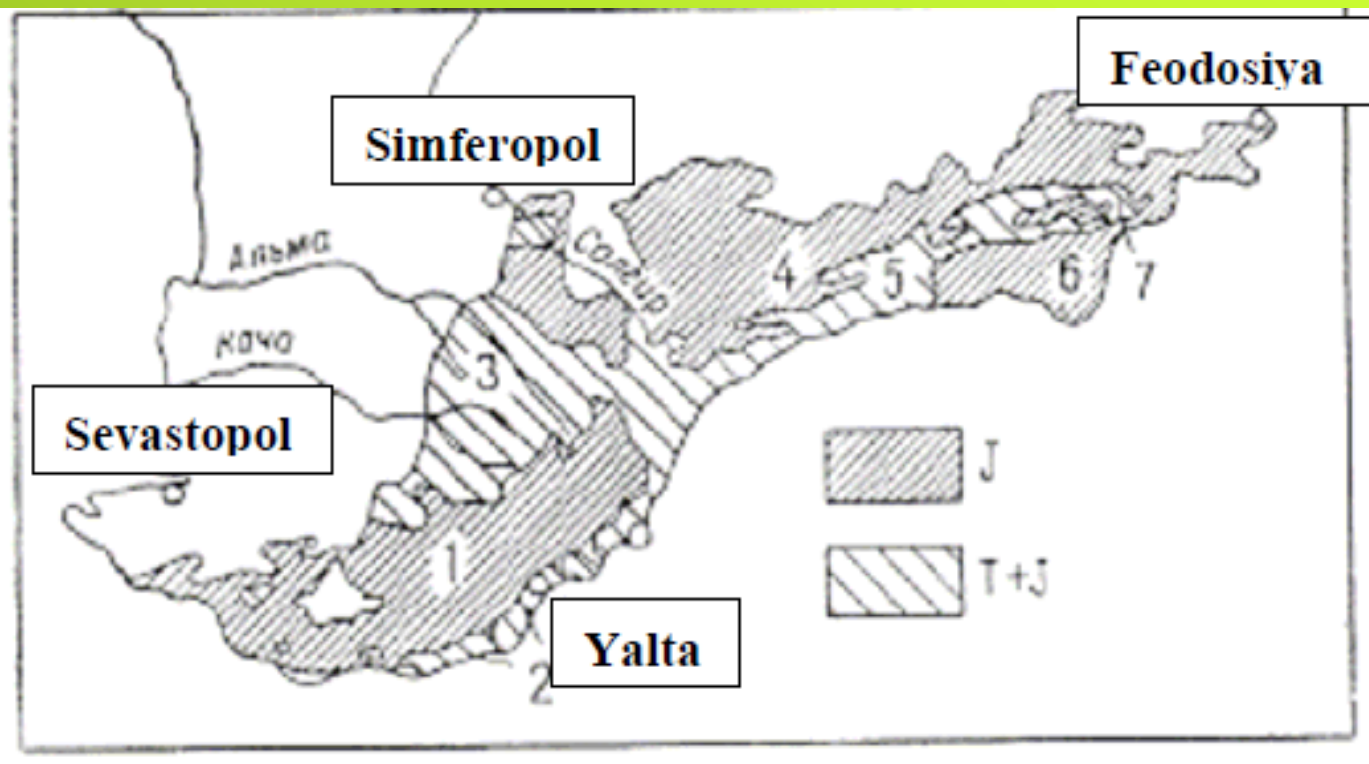


Figure 2.2.7. Map of the exposure localities and tectonic zonation for Jurassic deposits of Mountain Crimea: 1 – SW Crimean synclinorium; 2 – Yuzhnoberezhnyi (“South beach”) anticlinorium; 3 – Kacha (Kachynskiy) anticlinorium; 4 – Eastern Crimean synclinorium; 5 – Tuak(skiy) synclinorium; 6 – Sudak(skiy) synclinorium; 7 – Sudak-Karadag fold system (Muratov M.V., Snegireva O.V., Uspenskaya E.A., 1972)



Figure CR1A. General view of Balaklava Bay

Sedimentology:

Description (Nikishin A.M., Baraboshkin E. Ju., Kopaevich L.F. – oral report) – Within Balaklava along the seashore cliff a thick unit of Upper Jurassic limestones and conglomerates is exposed (Fig. CR1A–B). Conglomerates have a terrigenous and carbonate cementation and contain huge boulders (Fig. CR1C). Limestones make up vertical cliffs (Fig. CR1D–G). Limestones contain corals and are characterized by paleocarst. Upper Jurassic rocks are transgressively covered by Lower Cretaceous (Fig. CR1E). Modern processes of abrasion and karst form many grottos (Fig. CR1F).

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: This validation point is located within the SW Crimean synclimorium

Petroleum systems information: No data

Locality: Chembalo Fortress, Balaklava region

Position: 44.29.38.62 N, 33.36.02.79 E

Age: Late Jurassic



Figure CR1B. Genoese Chembalo Fortress stands upon Upper Jurassic conglomerates and limestones



Figure CR1C. Upper Jurassic red conglomerates (left) cover gray limestones (middle and right).



Figure CR1D. Sea cliffs made up by Upper Jurassic limestones



Figure CR1E. Lower Cretaceous terrogenous rocks covering Upper Jurassic limestones at the Vasili Gully in the vicinity of Balaklava



Figure CR1F. One of the innumerable grottos in Upper Jurassic limestones



Figure CR1G. General view of the Upper Jurassic section from the Black Sea

Locality: Baydary Gate, Foros region

Position: 44.24.22.55 N, 33.46.55.51 E

Age: Late Jurassic

Sedimentology:

Description - Within Baydary Gate area Oxfordian–Tithonian mainly carbonate including reef deposits are exposed (Figs. CR2A–C)

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts

Regional significance: From the Baydary Gate one could see the steep nearly vertical slope faced to the Black Sea that marks the border between South-Crimean orogen and Black Sea depression (the second place where it can be seen is a point no. 9 – Ai-Petry). This validation point is located at the SW Crimean synclinorium.



Figure CR2A. A view to Upper Jurassic limestones from the Baydary Gate. On the single cliff a Voskreseniya (“Ressurrection”) Church stands (middle).

Petroleum systems information: No data



Figure CR2B. A view to Upper Jurassic limestones from the beach (East, to the left) and to the Voskreseniya (“Ressurrection”) Church standing on the single cliff (to the right).



Figure CR2C. A view to Upper Jurassic limestone unit dislocated by series of thrusts (East). In the front is a Voskreseniya (“Ressurrection”) Church.



Figure CR3A. Taraktash Mt. View from the Dachnoe village. Top of the mountain is comprised by Upper Jurassic limestones



Figure CR3B. Top of the Lyagushka mountain is comprised by Upper Jurassic limestones (Oxfordian?) surrounded by Oxfordian(?) conglomerates

Locality: Dachnoe village, Taraktash and Lyagushka (“Frog”) Mts., Sudak region

Position: 44.24.22.55 N, 33.46.55.51 E (Lyagushka Mt.)

Age: Late Jurassic

Sedimentology:

Description (Nikishin A.M., Baraboshkin E. Ju., Kopaevich L.F. – oral report) – In the vicinity of Taraktash (Fig. CR3A) and Lyagushka (Fig. CR3B) Mts. a system of Late Jurassic (Oxfordian?) reef buildings is situated in the unit of conglomerates, sandstones and shales (Fig. CR3C) possibly of the same (Oxfordian?) age.

Interpretation – terrigenous units are interpreted as facies starting from alluvial up to turbiditic. Source of the terrigenous input (denudated land) is proposed to be located to the North. Reef massifs have discussional contacts with the surrounding terrigenous rocks. They can be formed *in situ* having aprons (tail area) of the disrupted limestones or as a huge slide bodies (olistolites). Shallow-marine environment.

Structure: Unit is tectonically imbricated and is broken by overthrusts.

Regional significance: Zone with the Late Jurassic reefs mark the preliminary position of the Northern edge of the Late Jurassic relatively deep-water rift basin. In the regional scale reef massifs are good collectors. Their typical porosity is about 3–15%. This validation point belongs to the Sudak sinclinorium.

Petroleum systems information: This reef belt can be found even along the Northern slope of the Great Caucasus (Khadyzhenskyi reef belt) but no big oil deposits are connected with it.



Figure CR3B. Upper Jurassic clays and sandstones comprise the main part of the Taraktash Mountain

Locality: Novyi Svet town & Veseloe

Village, Novyi Svet region

Position: 44.41.34.28 N, 33.42.19.85 E

(Veseloye)

Age: Late Jurassic

Sedimentology:

Description (Nikishin A.M., Baraboshkin E. Ju., Kopaevich L.F. – oral report) – In the studied region the following deposits of the same age different in composition and origin are distributed:

1. Reef massif facies,
2. Back reef apron facies
3. Fore reef apron facies
4. Alluvial fan facies
5. Basin slope (hemipelagic) facies

Description and interpretation - Reef massif facies. In the vicinity of the Veseloye village two conical reef buildings of the pinnacle type can be observed (Fig. CR4A). First (Fig. CR4A) is located just near the bus stop inside the village. Second can be found 1.5 km to the West on Sudak–Morskoye highway from the first one. Reefs are presented by pointed top Mountains of 100–150 m high build from massive-bedded dark gray coral, stromatolithic, stromatiporic, organogenetic-clastic limestones facially changing into sandy-clay deposits with the beds of organogenetic-clastic and coral limestones. The section of the analogous building can be observed in the Shalyapin Grotto (Fig. CR4B, C). The biggest reef massif – Sokol (“Falcon”) Mt. is situated between Sudak and Novyi Svet (Fig. CR4D–G).



Figure CR4A. Oxfordian chaetetid-coral-stromatoporate pinnacle with the exposed central part.



Figure CR4B. Pinnacle of Shalyapin Grotto, Novyi Svet



Figure CR4C. Part of pinnacle of Shalyapin Grotto, Novyi Svet



Figure CR4D. View from the plane (South) to the reef building of the Sokol ("Falcon") mountain



Figure CR4E. View from the Perchim Mt. (North) to the Sokol Mountain



Figure CR4F. View from the Sudak town (East) to the Sokol Mountain (left)

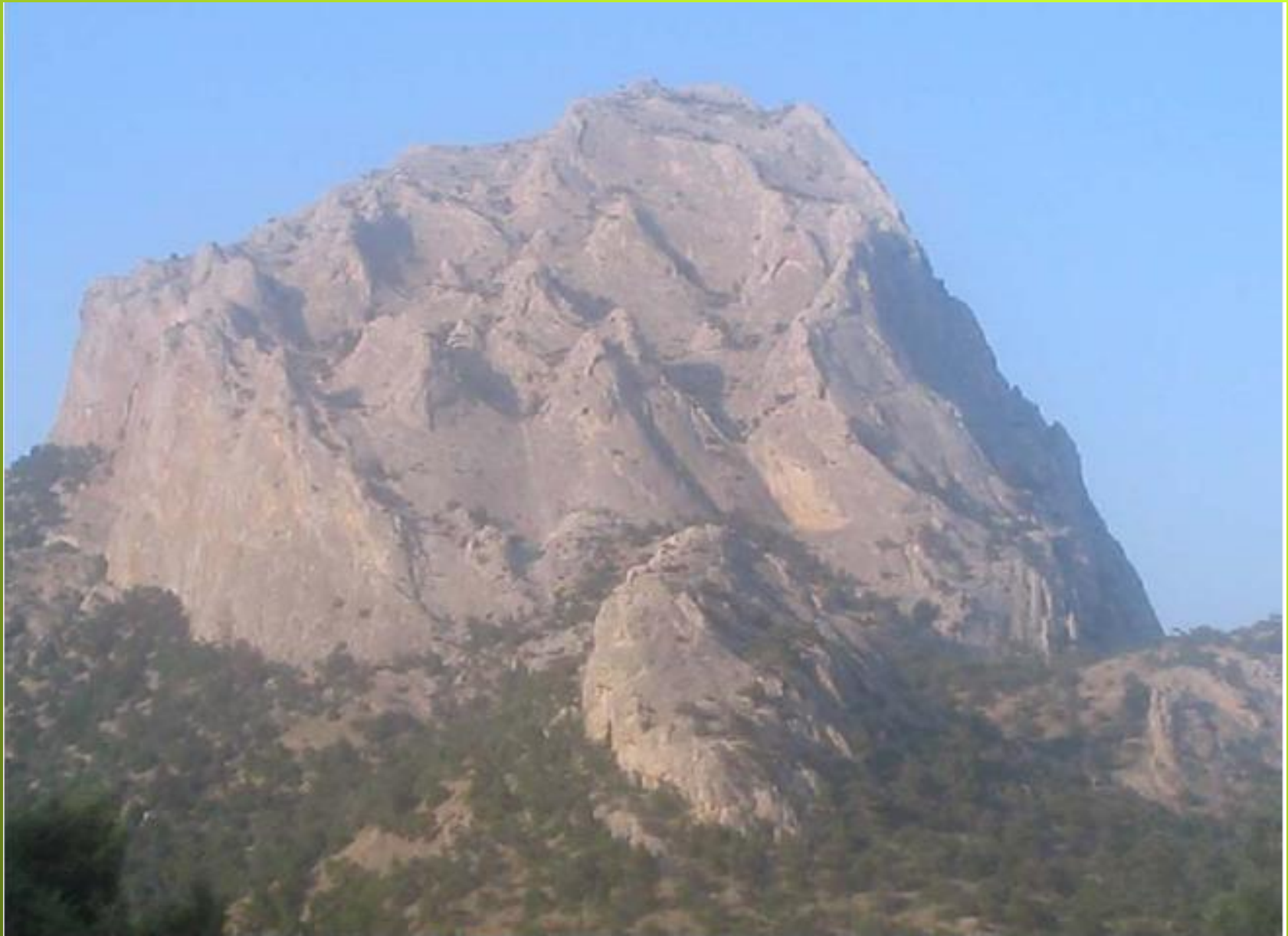


Figure CR4G. View from the Novyi Svet (West) to the Sokol Mountain

Fore reef apron facies. Beyond the bus stop in the Veseloye village a clay unit with clastic semi-rounded parts of coral and organogenetic-clastic limestones of the visual thickness 9 m can be located. The disruption of the reef massif can be caused by strong tempests and currents existed in the basin. The close position of the reef building is proved by the weak roundness of the limestone parts.

Back reef apron facies. From the South reef side (steep slope) faced to the Sudak–Morskoye highway a unit of non-stratified bituminous organogenetic-clastic limestones, comprising a few lens bodies of 10 m thick. These bodies have an abrupt boundaries with the fan unit presented by conglomerate-sandstone-clay and gradual with terrigenous-carbonate turbiditic unit. The absence of sandy, clayey material and presence of huge blocks of sandstones in limestones prove their slide nature. This is also proved by the absence of bedding, sharp boundaries with the surrounding rocks. Non-bedded limestones along the extension transform into turbidites that prove the presence of the tectonic bench on which reefs were formed.

Alluvial fan facies. These facies are presented by coarse material of the mountain river. Pebble is presented by products of denudation of the mountain including such rocks as plagiogranites, quartz rocks, sandstones, siltstones. Conglomerate matrix is a unwashed oligomictic feldspar gravels sandstones (quartz and lithoclastic prevail, clayey cementation is developed) typical for deposits of the submarine fans. The submarine nature is proved by the presence of the typical sea fauna – mollusks, algae, worms, echinoids, bryozoans. Conglomerate beds represent the maximal sea level, fine-grained sandstones and background (phon) clays characterize the minimal sea level. Thus these are the submarine river-channel alluvial deposits of the deep part of avandelta. Avandelta formed the alluvial fan.

Basin slope (hemipelagic) facies. These facies are characterized by sand-clay unit with rare beds of oragonogenetic-clastic limesones, by presence of the marine

fauna, plant detrit and remnants of the became charred (coalized) plant trunks. This can be explained as a formation of deposits in the marine environment but near the land. Amongst sandstones unsorted and fine-grained mainly quartz with clayey cementation prevail. Usually sandstones with carbonate cementation occur. Sandstones with the pore clay cementation may be the result of the terrigenous input into the open sea. Phone background clays have subordinate significance.

The observation of facies can be continued at the next point (no. 5).

Some schematic charts of sections and sedimentology data is given on Figs. CR4E–G.

Structure: Unit is tectonically imbricated and is broken by overthrusts

Regional significance: This validation point belongs to the Sudak sinclinorium.

Petroleum systems information: No data

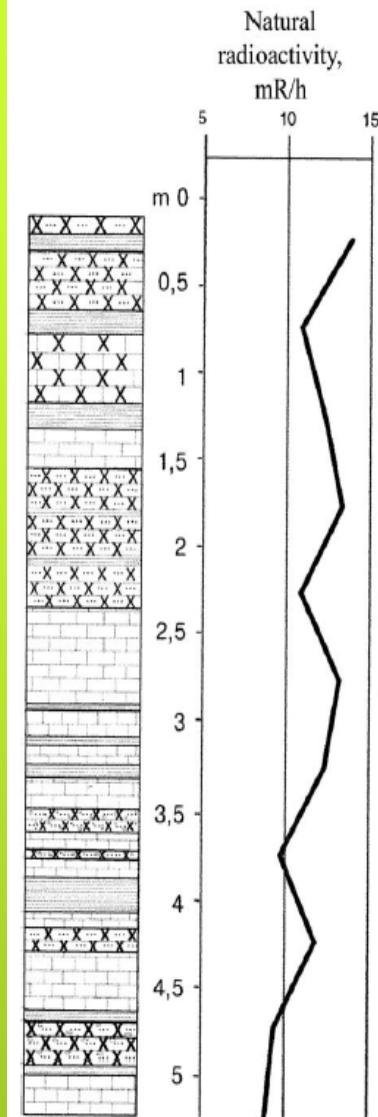


Figure CR4E. Stratigraphy and radiometry of fore-reef turbidite deposits in the vicinity of Veseloye village (compiled by E.Ju. Baraboshkin)

CR4

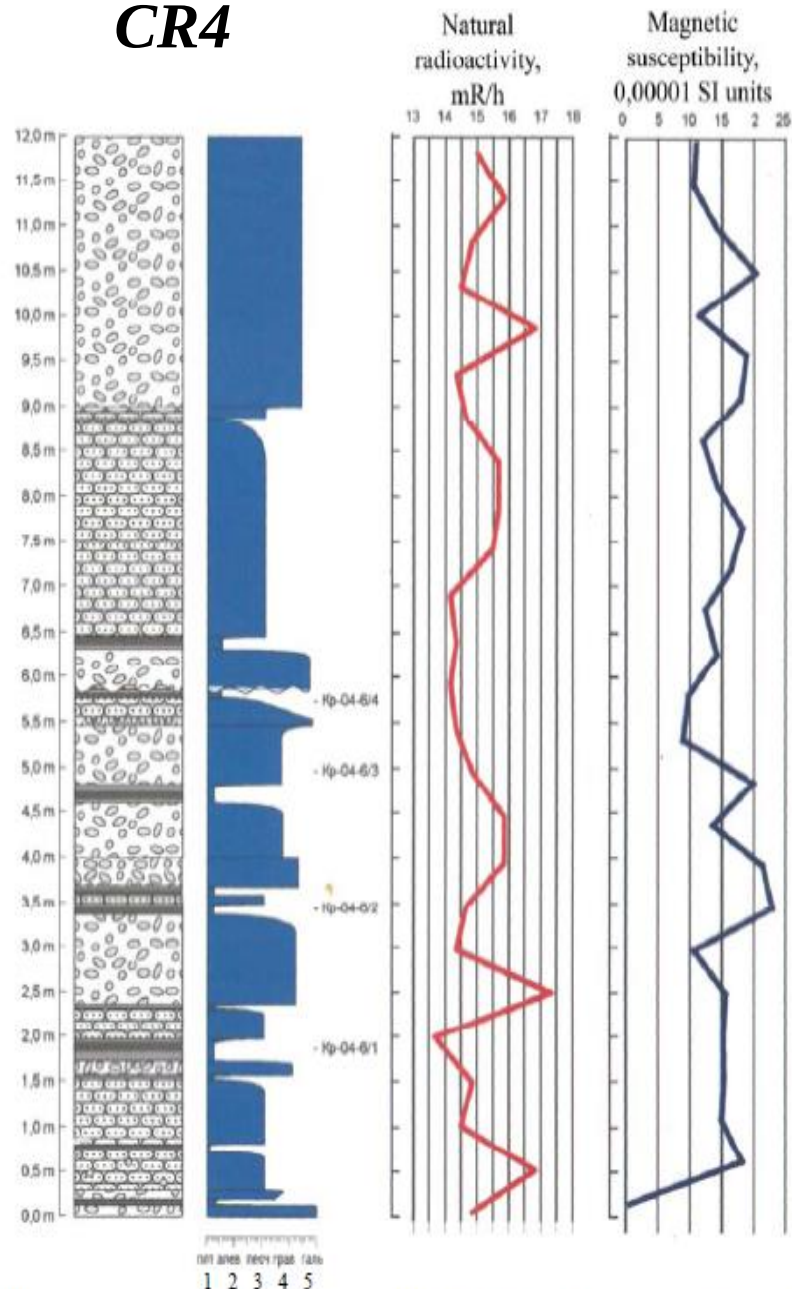
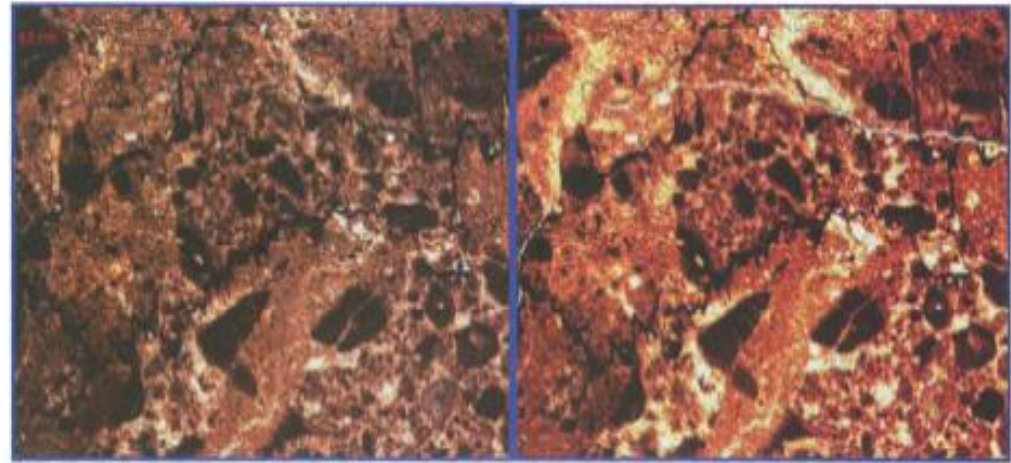
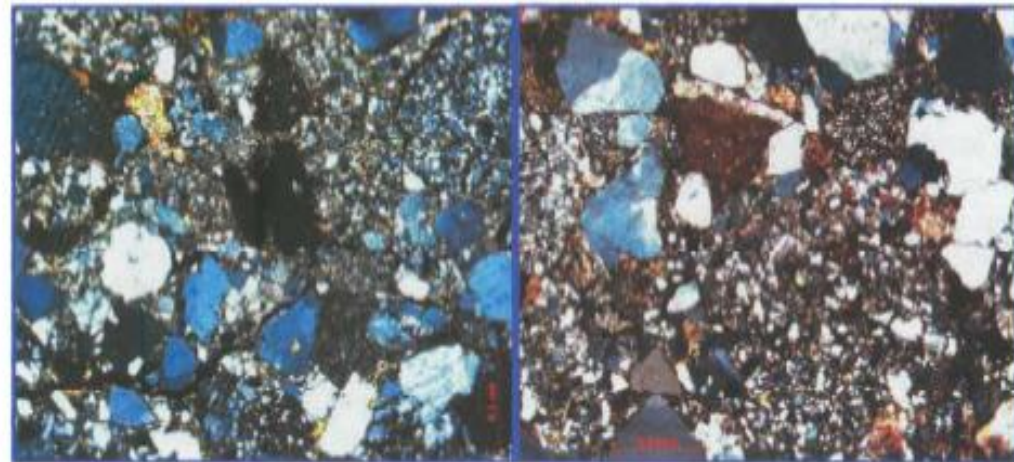


Figure CR4F. Stratigraphy and sedimentology of alluvial fan deposits in the vicinity of Veseloye village (compiled by E.Ju. Baraboshkin): 1 – dust (pelite); 2 – silt; 3 – sand; 4 – gravel; 5 – pebble.

Field trip. Validation points

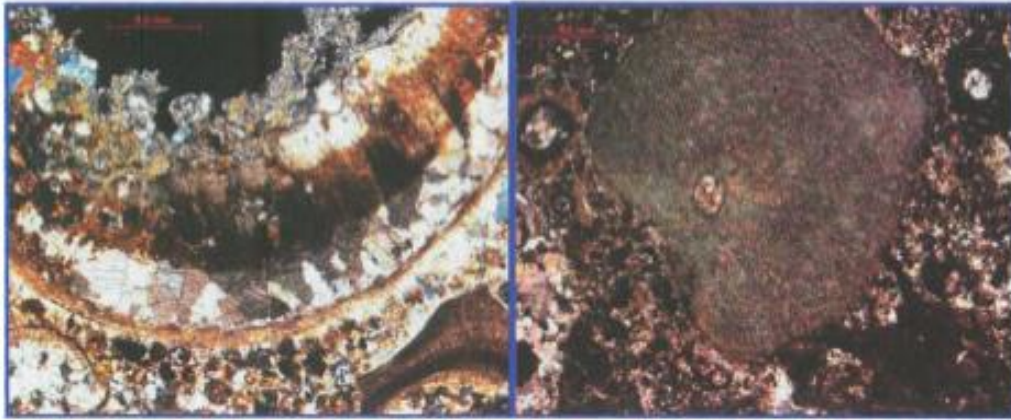


Re-crystallized grainstones with stylolites filled by bitumen from landslide facies. With analyzer (left), without – (right)



Poly-grained polymictic sandstones from alluvial fan facies. With analyzer.

Figure CR4G. Microphotographs of few facies in the vicinity of Veseloye village (compiled by E.Ju. Baraboshkin)



Re-crystallized bioclastic (bivalves – left, crinoids – right) packstones from turbidite facies. Pores are filled by sparite cement. With analyzer.

Figure CR4G. Microphotographs of few facies in the vicinity of Veseloye village (compiled by E.Ju. Baraboshkin)

Locality: *Papaya-Kaya & Karaul-Oba Mts., Novyi Svet region*

Position: *44.49.21.60 N, 33.50.23.72 E (Papaya-Kaya Mt.), 44.99.00.48 N, 35.53.46.68 E (Karaul-Oba Mt.)*

Age: *Middle-Late Jurassic*

Sedimentology:

Description – *lateral change of different terrigenous and carbonate Middle–Late Jurassic facies (§4, previous point) can be seen in the vicinity of Papaya-Kaya (Fig. 5CRA, B) & Karaul-Oba (Fig. 5CRC, D) Mts. These mountains are mainly built from Upper Callovian reef limestones and Lower–Middle Callovian carbonate-terrigenous units (Muratov, 1967)*

Interpretation - *Shallow-marine environment.*



Figure CR5A. *View to Papaya-Kaya from the NW*

Structure: Unit is tectonically imbricated and is broken by overthrusts

Regional significance: This validation point belongs to the Sudak sinclinorium.

Petroleum systems information: No data



Figure CR5B. View to Papaya-Kaya from the SE

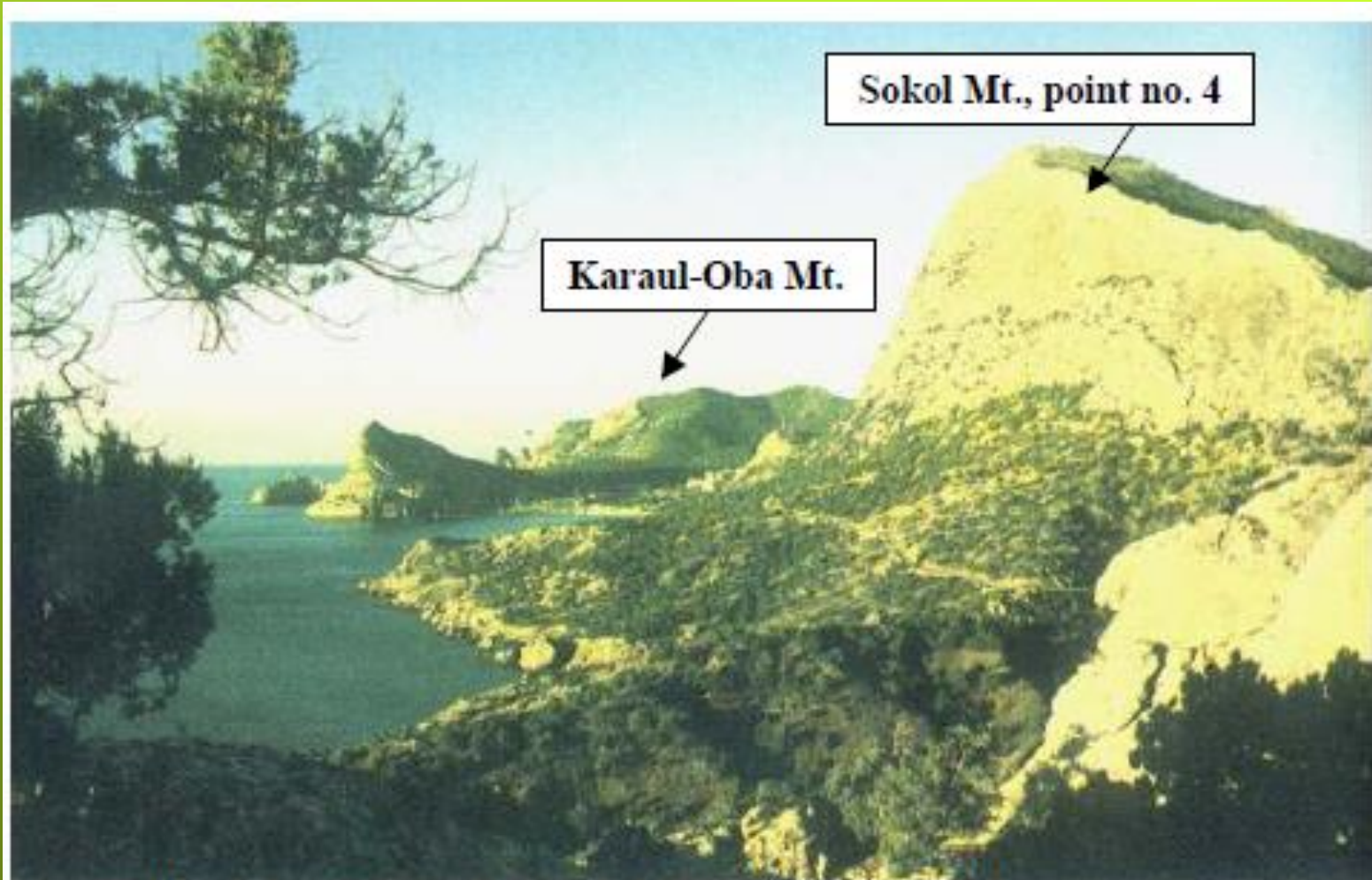


Figure CR5C. View from the East to Sokol and Karaul-Oba Mt.



Figure CR5D. View to Karaul-Oba Mt. from the SE

Locality: Chatyr-Dag Plateau & Emine-Bair-Khosar Cave, Alushta region

Position: 44.48.01.09 N, 34.17.23.89 E (Cave)

Age: Late Jurassic

Sedimentology:

Description – Chatyr-Dag Plateau is covered by innumerable karst craters (Fig CR6A). The Emine-Bair-Khosar cave is situated inside the Plateau (Fig CR6B) within the massive Upper Jurassic limestones and formed by karst process. Gradient (incline) of the cave to the North is generally the same as the gradient of limestones. The last lies steeper than relief (Fig. CR6C). The underground galleries of the cave are 1460 m long and more than 120 m deep. Here are many stalactites, stalagmites and other wandering forms (Fig. CR6D–F) are found. In the cave an innumerable finds of Pleistocene fauna was made that fall down through the karst wells (Fig CR6G). Paleontologically cave is characterized by separate bones and even whole skeletons of mammoths, cave bears, woolly rhinoceros (horn-nose), deers e.t.c. (Fig CR6H–I)

Interpretation - Shallow-marine environment.

Structure: Unit is tectonically imbricated by a series of thrusts that repeat section for many times (Fig. CR6J). Level of the cave can coincide with zones of tectonic fissuring (cleat) and the gently sloping overthrust.

Regional significance: This validation point is located at the Eastern-Crimean synclorium

Petroleum systems information is given in the text and tables inside §6.



Figure CR6A. Karst hollows in the Upper Jurassic limestones in the Chatyr-Dag Plateau



Figure CR6B. The surface of the Chatyr-Dag Plateau



Figure CR6C. Bedded limestones lay steeply then relief



Figure CR6D. Stalagmites in the cave



Figure CR6E. Variety of cave wandering forms



Figure CR6F. Columns – stalagnates in the cave



Figure CR6G. The natural well is an entrance into the cave



Figure CR6H. Skeleton of the bison fallen down through the karst hollow



Figure CR6I. Skeleton of the deer fallen down through the karst hollow

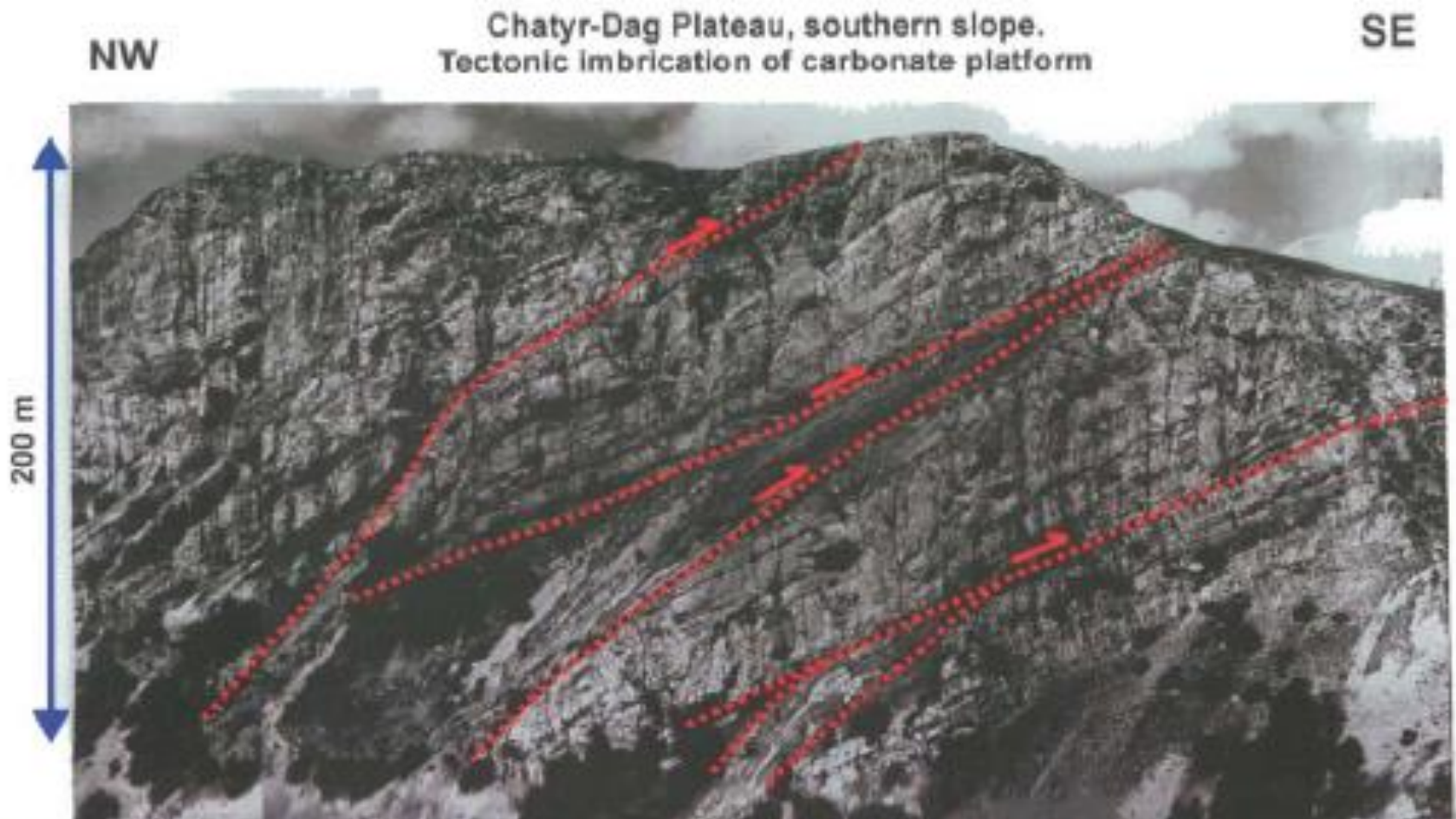


Figure CR6J. Scheme of tectonic imbrication of Chatyr-Dag Plateau (compiled by E.Ju. Baraboshkin, A.M. Nikishin)

Field trip. Validation points

CR7

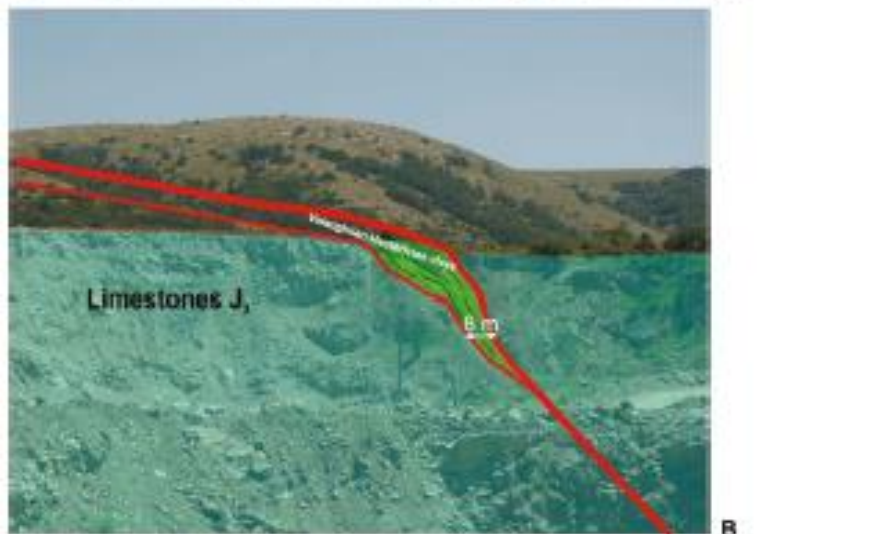


Figure CR7. A – Zone of tectonic contact between Upper Jurassic limestones and Valanginian–Hauterivian clays. B - Scheme of composition of Lower Cretaceous deposits of tectonic wedge in the Upper Jurassic limestones in the Mramorny Quarry (Nikishin et al., 2006)



Figure CR7C. View to the carbonate platform destroyed by karst in the vicinity of Mramornoye village and to the Quarry (in the front). Karst hollows in the Tithonian limestones are filled by Lower Cretaceous clays (grass crowding (gathering) marked by red arrows).

Structure: Upper Jurassic limestones were at least two-times tectonically deformed. First event was before Valanginian – the Late Kimmerian phase of folding and overthrusting widely presented in Crimea. Second phase was after Cretaceous probably in Oligocene–Neogene when the system of overthrusts occurred. Between them a wedges of Lower Cretaceous can be found. Marblized limestones contain a lot of modern (open) fissures (chip and isolation (separation) fissures and sliding mirrors) and the traces of ancient fissure systems and caverns. All the fissures have a tectonic origin. Two ancient fissure systems and caverns existed.

First is presented by small fissures and caverns filled by relatively homogenous secondary calcite. Second is a system of sufficiently big fissures and empties filled by clasted breccia of the surrounding rocks “submerged’ into the red carbonate matrix. The main orientation of the ancient fissures is submeridional.

Modern fissuring is presented by fissure systems of separation and sliding mirrors of the displacement and displacement-overfault origin. Stylolites and chip-fissures are lesser distributed.

Stylolites have NE-SW extension and ESE (120°) main declining direction. Angle of declining is rather steep ($48\text{--}85^\circ$). Stylolites mark the sublatitudinal compression in ESE–WNW direction.

Chip-fissures have 2 main system of orientation: sublatitudinal (107°) and SE–NW (145°). The last are lesser expressed. The conclusion about the sublatitudinal ESE–WNW direction of the main axis of compression is based upon the evidence that chip-fissures are located at the sharp angle to the axis of compression.

Modern chip-fissures are unclear seen and are parallel to the main axis of the compressing tensions (stresses) σ_3 .

Sliding mirrors have mainly ESE extension. Hatching marks main displacement in SE–NW direction. The axis of shift is slightly inclined to the East that explain the main distribution of the shift-overfault dislocations.

The relation between right and left horizontal and with vertical component displacements (shifts) is characterized by small domination (20%) of the left ones.



Figure CR7C. View to the carbonate platform destroyed by karst in the vicinity of Mramornoye village and to the Quarry (in the front). Karst hollows in the Tithonian limestones are filled by Lower Cretaceous clays (grass crowding (gathering) marked by red arrows).

Analysis of paleostreching shows the direction of the main axis of compressing σ_3 is ESE 116°.

Modern open fissuring is very abundant and reaches up to 6%. Fluid migration mainly proceeds along the axis of maximal tension (NNW 27°). On the scheme (Fig. CR7D) two possible scenarios of overthrust origin in the Mramornyi quarry are shown.

Regional significance: It is a unique place to study tectonic kinematics to understand the origin the Crimean orogen. Schematic map is given on Fig. CR7E. This validation point belongs to the Eastern-Crimean synclinorium.

Petroleum systems information:

Limestones are karsted and in the paleo-karst places one could see:

1. formation of cavities filled by big calcite cristalls (speleothems). Usually a small inner cavity is empty;
2. filling of the karst rocks of the few generations;
3. filling of the karst by sea clays.

From the mentioned types only the first can be interested as a potential reservoir.

Extent of fissuring is up to 6%.

Some microphotographs are given on Fig. CR7F. Other data is given in the text and tables inside §6.

Field trip. Validation points

CR7

The map shows the Mramornoye (Mramornoye) area in the Krasnodar Krai. It features a grid of latitude and longitude lines. The area is divided into several regions, including the 'Krasnodar' and 'Krasnodar' settlements. The map includes a scale bar (0-100 km) and a north arrow.

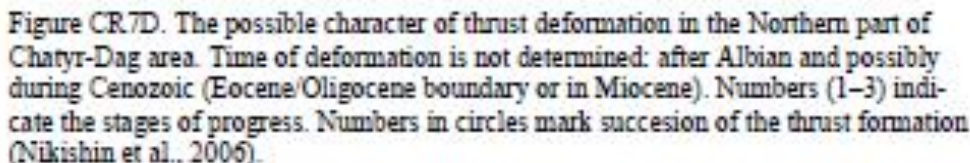
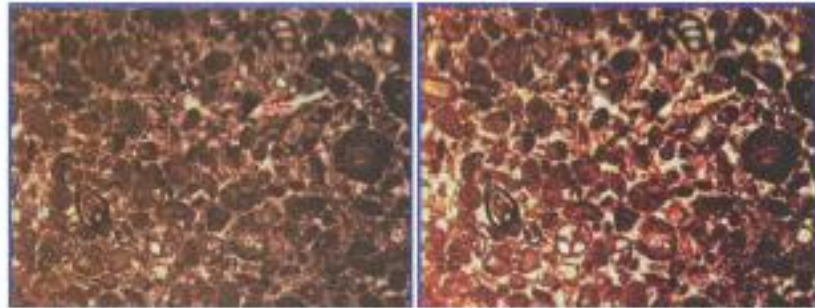
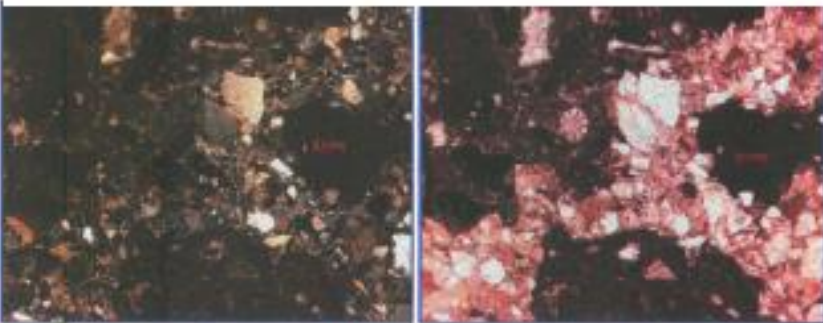


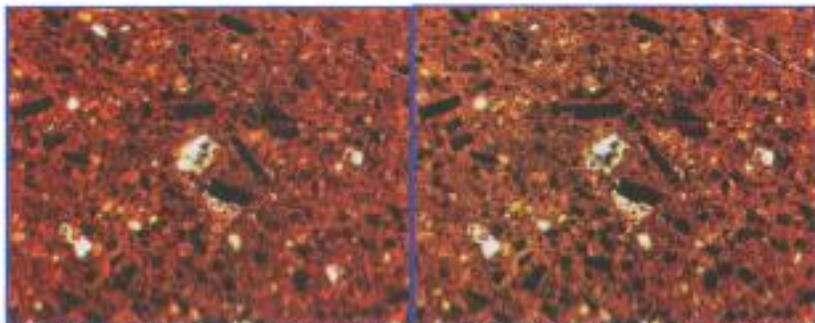
Figure CR.7E. Geological map of Mramornyi Quarry compiled by B.T. Yanin & E. Ju. Baraboshkin



Upper Jurassic grainstone with sparite cementation of pores filled by bitumen from landslide facies. With analyzer (left), without – (right). Northern side of Quarry.



Upper Jurassic grainstone with terrigenous input and sparite cementation of pores. With analyzer (left), without – (right). Northern side of Quarry.



Filling of karst empty space in Upper Jurassic grainstone. With analyzer (left), without – (right). Northern side of Quarry.

Locality: Demerdzhi-South Mt., Alushta region

Position: 44.44.56.27 N, 34.23.56.74 E

Age: Late Jurassic

Sedimentology:

Description – The main feature of the Demerdzhi Mountain (Fig. CR8A–C) is that it is comprised by conglomerate unit of 1 km thick. Conglomerates demonstrate a column (bastion) form of weathering (Fig. CR8D). In the lower part conglomerates are coarser with the sandy cement. In the upper part carbonate cement prevails and conglomerates are interbedded by limestones that form a relatively steep slope (Fig. CR8C, E). Pebbles include different Paleozoic (and Pre-Cambrian?) granites and shales (the

rocks of the Late Paleozoic basement), Permian and Triassic limestones (deposits of the sedimentary cover), rocks of the Tavricheskaya Formation (Triassic–Lower Jurassic), Mid-Jurassic volcanic rocks.

Age of conglomerates is not precisely determined (Oxfordian – Kimmeridgian - ?).



Figure CR8A. View to Demerdzhi-South Mt. from SW

Description of the section (Fig. CR8F; Chernov, 1963).

.Basal member. $J_3ox_1^1$. Weakly cemented by sandy-clayey matrix strongly ferruginated boulder–huge pebble conglomerates. Unit with the angle unconformity cover flysh of the Tavricheskaya Formation (T_3-J_1). Thickness is 20–50 m.

.Middle member. $J_3ox_1^2$. Strongly cemented by sandy-clayey matrix conglomerates with pebble of the huge and medium size with lenses and thin beds of gravelites, sandstones and rare argillites. Thickness is 70–150 m.

.Upper member. $J_3ox_1^3$. Strongly cemented by sandy-carbonate matrix conglomerates with pebble of the huge and medium size with lenses and beds of gravelites and sandstones. Thickness is 200–800 m.

.Rorakskyi Horizon. $J_3ox_2^1$. Strongly cemented by carbonate matrix conglomerates with pebble of the medium size with d thin beds of sandy limestones that contain a rich fossil complex of gastropods: *Natica rupelliensis*, *N. milepura*, *Aurordella* sp. indet., *Fibula aitodori*, *F. aviformis*. Thickness is 150–200 m.

.Sekvanskyi Horizon. $J_3ox_2^2$. Strongly cemented by carbonate matrix conglomerates with pebble of the medium and small size alternated with coarse-grained gravelites and sandstones. Thickness is 400 m.



Figure CR8B. View to Demerdzhi-South Mt. from Alushtra-Sudak highway (South)



Figure CR8C. View to Demerdzhi-South Mt. from SW

M.V. Muratov was the first who decided that the source of the terrestrial input was situated to the South. He called it Tuakskoe Rise. A good study allowed V.G.Chernov (1970) to reconstruct the hypothetical section including rocks from Proterozoic to Lower Jurassic of this assumed land (denudation area) existed within the modern borders of the Black Sea.

Interpretation - Shallow-marine environment.
Conglomerates have marine origin and were formed in the active rift basin

Structure: Unit has possible thrusts so section is repeated for many times.

Regional significance: This validation point is located at the Eastern-Crimean synclinorium

Petroleum systems information: No data

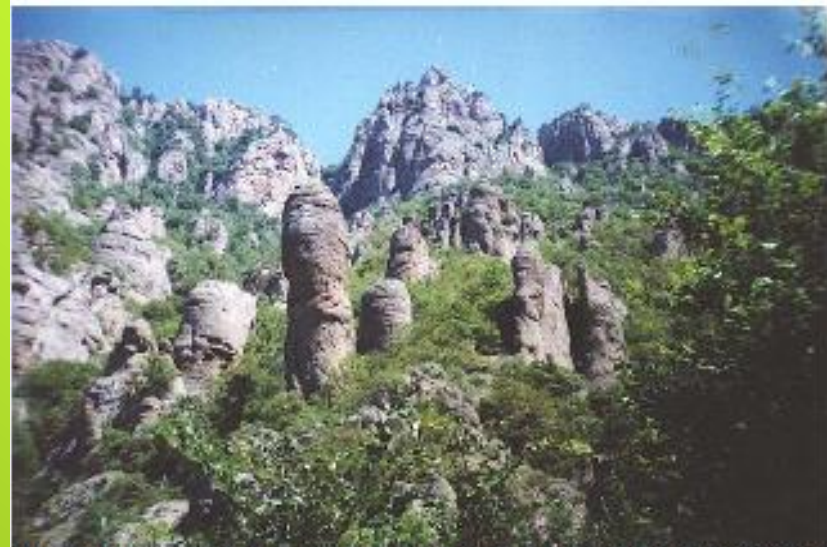


Figure CR8D. Column forms of weathering in conglomerates form a mystic landscape in the "Ghost Valley"



Figure CR8E. Upper part of the section

Locality: Ai-Petry Plateau, Yalta region

Position: 44.28.08.29 N, 34.04.11.05 E

Age: Late Jurassic (Kimmeridgian–Tithonian)

Sedimentology:

Description – Plateau is built from Upper Jurassic carbonates of a row of facies that are more than 600 m thick and 2 km wide. Bedded, massive, reef, oolitic, oncoidal, marly, sandy limestones and sandstones can be found (Fig. CR9A–E). The main part of the Ai-Petry mountain is composed of hard, unbedded massive limestone that build steep 600 m high cliffs in the Southern part of the Mountain. Ai-Petry massive limestones gradually pass, both laterally mountainward, into thick- and medium bedded limestones. Owing to tectonic movements both massive and bedded limestones are tilted northwards at an approx. 12 degrees. Based on coral findings the Ai-Petry complex is interpreted as a coral barrier reef. Kimmeridgian–Tithonian (instead of former Oxfrodian – Early Kimmeridgian) age was received after recent study of foraminifers (Krajewski, Olszewska, 2006).

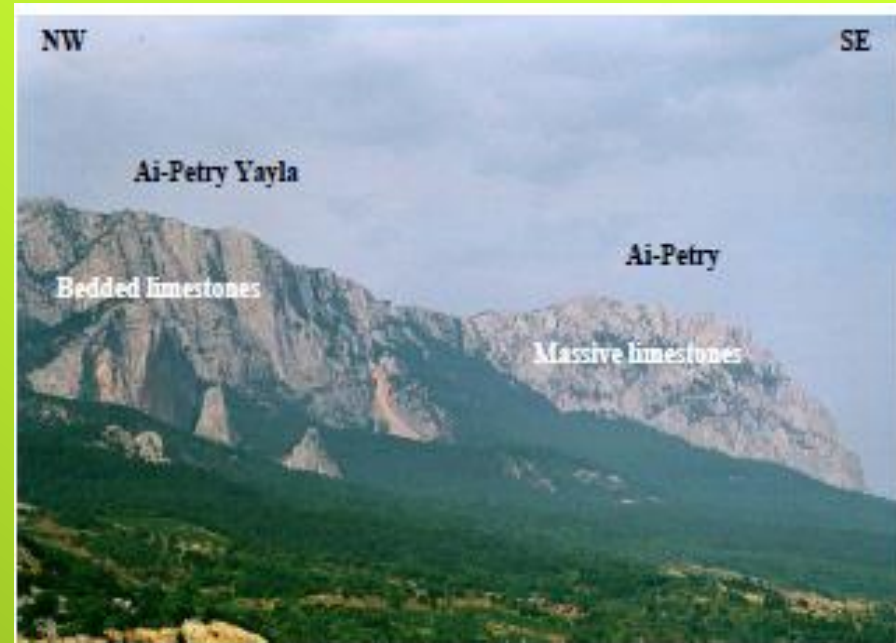


Figure CR9A. View to Ai-Petry Plateau from Simeiz



Figure CR9B. View to Ai-Petry Plateau from the West

In the lower part of the section packestone, grainstone, rudstone dominate with some portion of wackestone and floatstone. The Upper part of the section is build up from wackestone and floatstone with some packestone, grainstone, rudstone and bounstone parts.

Foraminifera assemblage (Fig. CR9F) includes very widespread in the Kimmeridgian and Tithonian and characterizing innner part of a carbonate platform *Pseudoyclammina*, *Rectocyclammina*, *Everticyclammina*, *Neokilianina*, *Labyrinthina*. Most of them colonized organogenic buildups and some of them (*Subbdeilloidina* and *Mohleria*) coul even have played a binding role by encrusting the buildup surface.

Throughout most of the section massive limestones appear to represent monotonous micritic or detrital rocks. Massive limestones belong to a stromatoporoid and microbial-algal microencrusters (Fig. CR9G), frequently of variable proportions and showing either appearence or complete disappearance of some faunal genera. Also occur oncolithic horizons, between 10 and 20 cm thick, and infrequent sandstone layers. The studied section includes mainly phaceloid forms: *Calamophylliopsis*, *Latomeandra*, *Stylosmilia* and *Microphyllia* which build small, patch reefs, usually 1 m in diameter. Their inner structure is poorly visible owing to considerable or complete recrystallisation of corals. Stromatoporoids (*Cladocoropsis mirabilis* Felix) occur much more frequently than corals. They form small colonial patches which usually develop on hard elements of the substratum. Stromatoporoids occur nearly always with *Lithocodium* (Fig. CR9G). Moreover, quite common are algae (dasycladacea, rarely Codiacea), small calcareous sponges, fragments of echinoids, bryozoans, and coprolites. The entire section includes a frequently occuring, characteristic assemblage of foraminifers and microencrusters.

Interpretation - Shallow-marine environment (outer platform and increased water energy) is prooved by foraminefera complex (*Mohleria*, *Nautiloculina*, *Protopeneropsis*, *Siphovalvulina*, *Subbdeilloidina*, *Troglotella*, “trocholins”, and ‘textulariids”). Corals, echinoids, bryozoans, sponges also indicate warm basin with normal salinity.

Structure: Carbonate massif is intersected by a system of thrusts and it's tectonic structure is not clear (Nikishin A.M., Baraboshkin E. Ju., Kopaevich L.F. – oral report).

Regional significance: From the top of the Plateau (1234 m high) one could see the wonderful landscape. At the same time the steep nearly vertical slope faced to the Black Sea marks the border between South-Crimean orogen and Black Sea depression. To the South from Ai-Petry in the Black Sea a Sorokin through is situated. It is an Oligocene flexure basin for the South-Crimean orogen. The main phase of it's submerging was at Maikopian (Oligocene- Early Miocene) time. The origin of the Sorokin through is possible to be caused by the start of overthrusting of the South-Crimean orogen onto area of Black Sea basin. This validation point is located at the SW Crimean synclinorium.

Petroleum systems information is given in the §6.



Figure CR9C. Peak of Ai-Petry. View from the North.



Figure CR9D. View to the top of Ai-Petry from the cable-way



Figure CR9E. View to the cliff of Ai-Petry from the cable-way

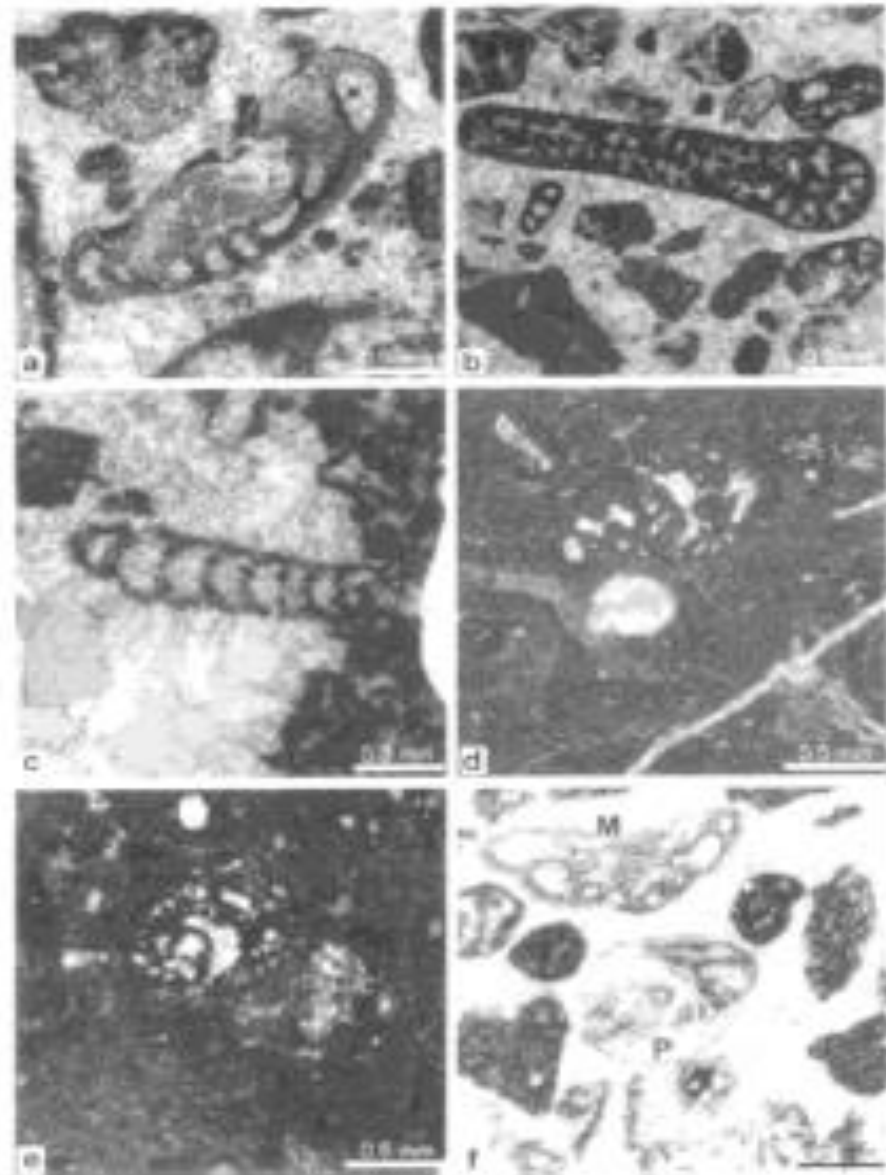


Figure CR9F. Examples of foraminifera occurring in the massive Ai-Petry limestones. a - *Mohleria basiliensis* (Mohler); b - *Labyrinthina mirabilis* (Weynschenck); c - *Everitticyclammina virguliana* (Koechlin); d - *Rectocyclammina chouberti* (Hottinger); e - *Pseudocyclammina sphaerica* (Hottinger); f - *Protopenelopis striata* (Weynschenck) (P) and *Mohleria basiliensis* (Mohler) (M) (Krajewski, Olszewska, 2006)

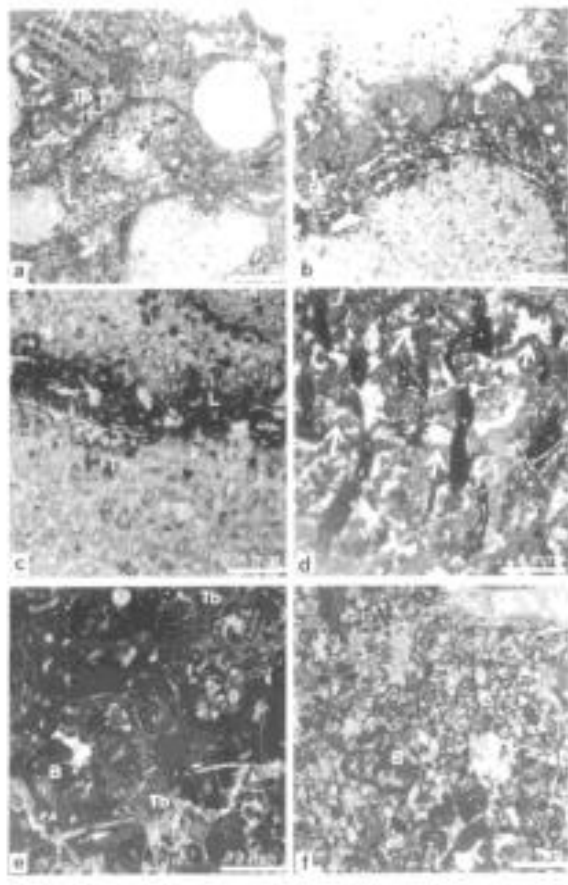


Figure CR9G. Examples of microencrusts from the massive Ai-Petry limestones. a – Packstone and framestone; numerous stromatoporoids bear *Lithocodium* (L) on their surfaces; packstones include also *Tubiphytes morronensis* (Tb). b-c – Framestone and wackestone; space between stromatoporoids frequently filled with *Lithocodium* (L) and *Troglotella* (T); d – framestone; sediment bound by numerous *Tubiphytes morronensis*. The presence of the rigid framework is documented by growth cavities (arrows); e – Packstone and grainstone; among intraclasts and microbial structures numerous *Tubiphytes morronensis* (Tb) and *Bacinella* (B) specimens occur; f – Packstone and grainstone; in the central part well visible *Bacinella* (B) which fills intra-grain pores and contributes to binding of loose sediment (Krajewski, Olszewska, 2006)

Locality: Ordzhonikidze & Yuzshnoye villages, Feodosiya region

Position (determined by Google Earth):

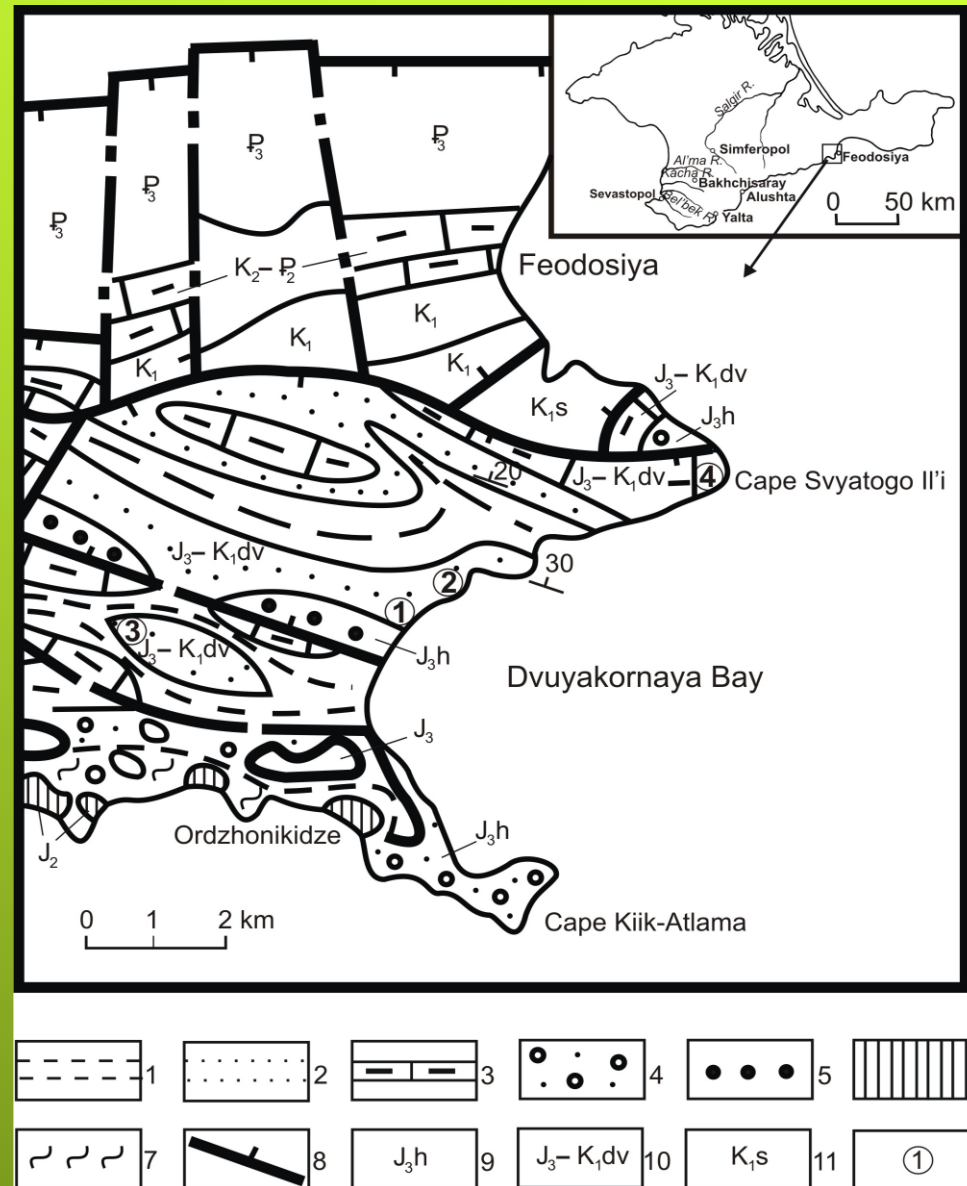
44.00.44.22 N, 35.25.29.41 E (Cape Svyatogo Il'i – Section 4); 44.59.38.91 N, 35.21.52.46 E (Section 2); 44.59.26.99 N, 35.21.54.59

Age: Late Jurassic

Sedimentology:

Description – In the vicinity of Ordzhonikidze a Jurassic–Cretaceous deposits can be observed (Fig. CR10A–C).

Figure CR10A. Schematic geological structure of the Feodosiya area (Arkad'ev et al., 2006) and location of examined Dvuyakornaya Formation sections: (1) clays, siltstones; (2) sandstones; (3) marls; (4) block conglomerates; (5) conglomerates; (6) volcanosedimentary rocks; (7) tectonites; (8) thrusts; (9) Khutoran Formation; (10) Dvuyakornaya Formation; (11) Sultanovka Formation; (12) numbers of examined sections: (1) Section 1, Dvuyakornaya Bay, (2) Section 2, Dvuyakornaya Bay, (3) Section 3 1 km southeast of the Yuzhnoe Settlement, (4) Section 4 in the Cape Svyatogo Il'i area



Lowest layers of the Dvuyakornaya Formation are exposed in the coastal cliff of the eponymous bay approximately 2 km north of the Ordzhonikidze Settlement (Fig. CR10D, Section 1). The following members (Arkad'ev et al., 2006) are exposed here (from the base upward):

Member 1: green gray clays (Fig. CR10E), compact, with local parallel bedding and ferruginate brown bedding planes; clays contain bun-shaped and lenticular concretions of more compact calcareous clay, being intercalated with rare thin (up to 0.5 cm) interbeds of brown limy sandstones. Ammonite species *Euvirgalithacoceras* cf. *tantalus* (Herbich) and *Subplanites* sp. were found 8 m above the member base; *Pseudowaagenia gemmellariana* Oloriz and *Lingulaticeras* cf. *Procurvum* (Ziegler) 2 and 4 m above these finds. At all levels, ammonites are accompanied by abundant bivalves *Bositra somaliensis* (Cox). The member yields also microfossils: foraminifers *Reophax giganties* A.-V., *Haplophragmoides chapmani* Crespín, *Melathrokerion eospirialis* Gorb., *Charentia evoluta* Gorb., *Textularia notcha* Gorb., *Textularia* sp., *Trochammina* sp., *Lenticulina dilecta* Putria, *L. attenuata* (Kueb. Et Zwin.), *Spirillina kubleri* Mjatl., *Trocholina alpina* (Leup.), *Discorbis* sp., *Epistomina ventriosa* Esp. et Sig., and ostracodes *Bairdia* sp. nov., *B. sp. 6*, *Cytherella krimensis* Neale, *C. tortuosa* Lubimova, and *Palaeocytheriodes groissi* Schudack.

The thickness is 20 m.



Figure CR10B Contact of the volcanic-sedimentary and clayey units of the Middle Jurassic near the Ordzhonikidze settlement



Figure CR10C. The exposure of Callovian–Oxfordian (?) clay and conglomerate unit above Ordzhonikidze settlement.

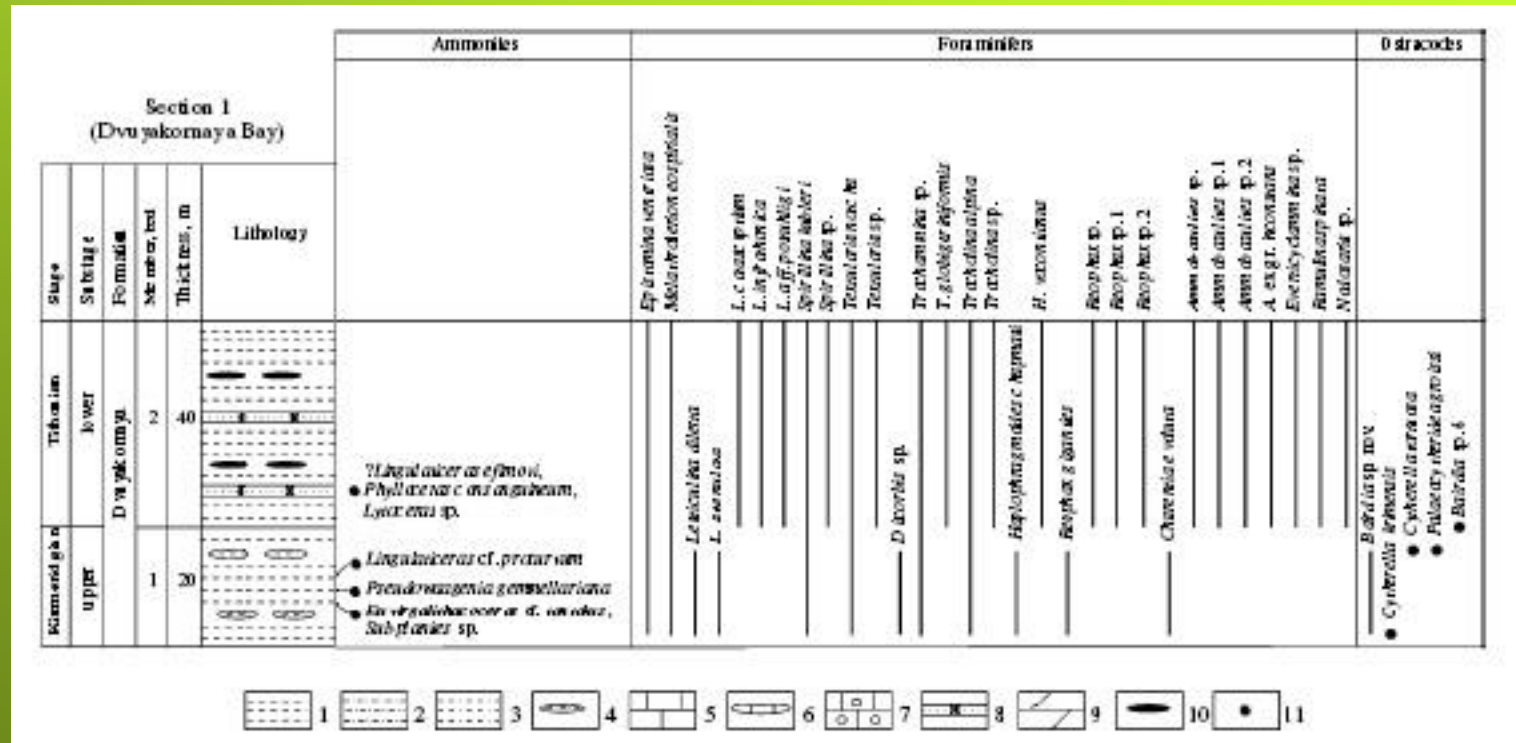


Figure CR10D (Arkad'ev et al, 2006). Distribution of ammonites, foraminifers, and ostracodes in Section 1: (1) clays; (2) siltstones; (3) sandy clays; (4) siltstone lenses; (5) limestones; (6) limestone lenses; (7) conglomeratic limestones; (8) calcareous sandstones; (9) marls; (10) siderite concretions; (11) ammonite and ostracode finds.



Figure CR10E Clays of the Dvuyakornaya Formation

Upper Kimmeridgian/Lower

Tithonian boundary. Member 2 (fig. 10CRF–G): greenish gray clays and dark to light gray siltstones with rare interbeds (1–3 cm in the lower part and up to 20–30 cm higher) of brownish gray fine- to medium-grained compact calcareous sandstones; siderite lenses and interbeds (20–30 cm) in sandstone have brown surface. At the level 10 m above the member base, sediments yield ammonites *Lingulaticeras efimovi* (Rogov), *Phylloceras consanguineum* Gemmellaro, *Lytoceras* sp., and bivalves *Aulacomia problematica* Furlani). Foraminifers identified in this member are *Reophax* sp., *Reophax* sp. 1, *Reophax* sp. 2, *Haplophragmoides vocontianus* Moullade, *Ammobaculites* sp. 1, *Ammobaculites* sp. 2, *A. ex gr.*

inconstans Bart. et Brand, *A. sp.*, *Melathrokerion eospirialis* Gorb., *Everticyclammina* sp., *Textularia* sp., *T. notcha* Gorb., *Trochammina globigeriniformis* (Parker et Jones), *T. sp.*, *Nodosaria* sp., *Lenticulina catascopeium* (Mitjanina), *L. infrathonica* K. Kuzn., *L. aff. postuhligi* K. Kuzn., *Ramulima spinata* Ant., *Spirillina* sp., *S. kubleri* Mjatl., *Miliospirella* sp., *Trocholina alpina* (Leup.), *T. sp.*, *Epistomina ventriosa* Esp. et Sigal, and undeterminable planktonic forms.

The thickness is 40 m.

The next interval is unexposed. Higher layers are studied near the benchmark 90.0 m inside the Dvuyakornaya Bay (Fig. CR10H, Section 2), where the following succession is exposed from the water level upward:

Field trip. Validation points

CR10



Figure CR10F. Upper Kimmeridgian – Lower Tithonian interval of the section

Member 3: greenish gray splintery clays (0.3–0.5 m) with parallel bedding, brown siderite concretions, and black plant detritus; they are intercalated with more compact sandy varieties and pinkish gray fine-grained detrital limestones (0.10–0.15 cm). Small poorly preserved ammonites *Ptychophylloceras* sp., *Holcophylloceras* sp., *Haploceras* sp., *Lytoceras* sp., and aptychi *Punctaptychus* cf. *punctatus* (Voltz), and *P. cinctus* Trauth. are found 1 m above the base.

Foraminifers of the member are represented by *Haplophragmoides* sp. 1, *H.* sp. 2, *Ammobaculites* ex gr. *inconstans* Bart. et Brand, *Textularia notcha* Gorb., *T. densa* Hoff., *Gaudryina chettabaensis* Sig., *Lenticulina* sp.1, *Lenticulina* sp. 2, *Spirillina helvetica* (Keub. et Zwin.), *S. kubleri* Mjatl., and *S.* sp.; ostracodes by *Bairdia* sp. nov. The thickness is 12 m.

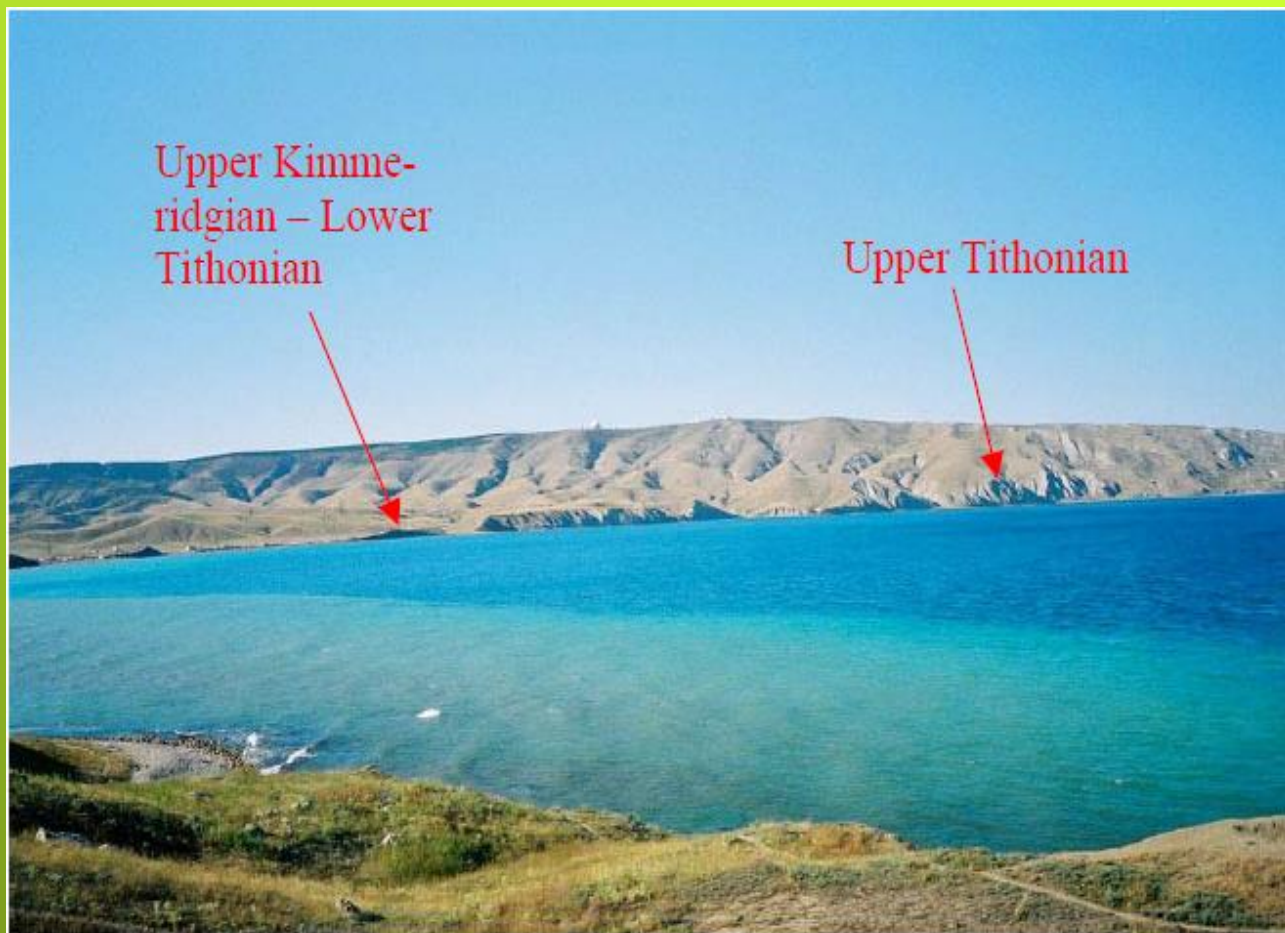


Figure CR10G. View to Dvuyakornaya Bay



4: Interval 8 m wide is unexposed.

Member 5: alternating dark greenish gray splintery clays and cream-colored fine-grained detrital compact limestones (0.05–0.10 m) with abundant furoids; limestone beds have the sharp lower and frequently ocherous upper boundary. In

the uppermost part of the member, a bed of massive limestone is 0.5 m thick. Sediments yield diverse fossils: poorly preserved ammonites *Haploceras* sp., *Lytoceras* sp.; aptychi *Punctaptychus cinctus* Trauth.; foraminifers *Haplophragmoides* sp. 2, *Ammobaculites* ex gr. *inconstans* Bart. et Brand, *Everticyclammina* sp., *Textularia notcha* Gorb., *Spirillina helvetica* (Keub. et Zwin.), *S. minima* Schaco, *S. sp.*, *Patellina turriculata* Dieni et Massari; and ostracodes *Bairdia* sp. nov., *Bairdia* sp. 7, *Bairdia* sp. 8, *Cytherella krimensis* Neale, “*Cythereis*” sp. 2, ?*Mantelliana purbeckensis* (Forb.), *Hechticythere* sp.

The thickness is 13.5 m.

Member 6: alternating dark greenish gray splintery clays (0.5–1.0 m), more compact lenticular siltstones (0.03–0.10 m), and pinkish gray fine-grained detrital compact limestones (0.03–0.10 m); some clay interbeds are highly ferruginate,

ocherous, brown to yellow in color. Ammonite *Ptychophylloceras* sp. is found in the middle of the member. Foraminiferal assemblage consists of *Reophax giganties* A.-V., *Haplophragmoides* sp. 2, *Ammobaculites* ex gr. *inconstans* Bart. et Brand, *Everticyclammina* sp., *Textularia densa* Hoff., *Spirillina helvetica* (Keub. et Zwin.), *S. sp.*, and *Patellina turriculata* Dieni et Massari.

The thickness is 12 m.

Member 7 is lithologically similar to the previous one, though comprising a relatively thick (0.4 m) bed of cream-colored fine-grained detrital limestones at the top. Among microfossils, there are foraminifers *Reophax giganties* A.-V., *Ammobaculites* ex gr. *inconstans* Bart. et Brand, *Everticyclammina* sp., *Spirillina helvetica* (Keub. et Zwin.), *S. sp.*, *Trocholina burlini* Gorb., and ostracodes *Bairdia* sp. nov., *Bairdia* sp. 7, *Cytherelloidea mandelstami blanda* Neale, *C. mandelstami mandelstami* Neale, *Schuleridea juddi* Neale, *Cypridina* sp., *Macrocypris* sp., and others.

The thickness is 15 m.

8: interval 15 m wide is unexposed.

Member 9: alternating greenish gray splintery and compact parallel-bedded clays (0.3–1.0 m), cream-colored to brown detrital compact limestones (0.1–0.5 m), and rare gray detrital calcareous sandstones (0.10–0.15 m); some limestones

beds consist of lenses up to 0.5 m long. Ammonites *Oloriceras schneidi* Tavera, *Ptychophylloceras* sp., and aptychi *Punctaptychus punctatus longa* Trauth. are found 2 m below the member top. The following foraminifers are dispersed through the member: *Ammobaculites* ex gr. *Inconstans* Bart. et Brand, *Melathrokerion eospirialis* Gorb., *Gaudryina chettabaensis* Sig., *G.* sp., *Lenticulina dilecta* Putria, *L.* cf. *macra* Gorb., *L. muensteri* (Roem.), *L.* sp., *Astacolus planiusculus* (Reuss), *Vaginulina duestensis* Reuss, *Spirillina kubleri* Mjatl., *S.* sp., *Discorbis crimicus* Schok., *D.* sp., and *Epistomina ventriosa* Esp. et. Sig. The ostracode assemblage consists of *Bairdia* sp. nov., *Quasihermanites implicata* Donze, and *Macrocypris* sp. The thickness is 16 m

10: interval 10 m wide is unexposed.

Member 11: irregularly alternating greenish gray splintery clays (0.3–1.0 m) and cream-colored detrital limestones (0.03–0.40 m), which are intercalated with brown siderite interbeds. Identified foraminifers are *Haplophragmoides*

globigerinoides (Haeusler), *Trochammina neocomiana* Mjatl., *T. globigeriniformis* (Parker et Jones), *Lenticulina immense* K. Kuzn., *L. gutata gutata* (ten Dam), *L. Muensteri* (Roem.), *L. undorica* K. Kuzn., *L. uspenskajea* K. Kuzn., *L.* sp., *Astacolus planiusculus* (Reuss), *Vaginulina duestensis* Reuss, *Spirillina helvetica* (Keub. et Zwin.), *S.* sp., *Trocholina infragranulata* Noth, and *Patellina turriculata* Dieni et Massari. Ostracodes are represented by *Bairdia* sp. nov., *Bairdia* sp. 7, *Cytherella krimensis* Neale, *Cytherelloidea tortuosa* (Lub.), *C.* ex gr. *tortuosa* (Lub.), *C. Mandelstami blanda* Neale, *Quasihermanites implicata* Donze, *Tethysia chabrensis* Donze, “*Xestoleberis*” sp. 1, *Macrocypris* sp., *Macrocypris* sp. 3, and others.

Thickness is 20 m.

Member 12 is lithologically similar to the previous one, though lacking siderite interbeds; limestone beds are relatively thicker (0.3–0.4 m). Characteristic foraminifer species are *Melathrokerion spirialis* Gorb., *Trochammina globigeriniformis* (Parker et Jones), *Lenticulina uspenskajea* K. Kuzn., *L. sp.1*, *L. sp. 2*, *Vaginulina duestensis* Reuss, *Spirillina helvetica* (Keub. et Zwin.), *Trocholina infragranulata* Noth, *T. alpina* (Leup.), and *T. elongata* (Leup.). The ostracode assemblage includes *Cytherella krimensis* Neale, *Cytherelloidea mandelstami blanda* Neale, *C. Tortuosa* (Lub.), *Cypridina* sp., *Bairdia* sp. nov., *Macrocypris* sp., and “*Xestoleberis*” sp. 1. The thickness is 10 m.

Belemnite *Pseudodivalia tithonica* (Opp.) is found in talus derived from the section lower part. The section continues further approximately 1 km southeast of the Yuzhnoe Settlement in the southern limb of the Sultanovka syncline (Fig. CR10I, Section 3). The following sediments are exposed in several small hills:

Member 13: dark green to locally gray clays, parallelbedded, splintery, intercalated with light gray coarse-grained calcareous sandstones (0.05–0.15 m) and containing lenslike siderite concretions up to 20–30 cm thick. The layer near the member base, clays contain bivalves *Aulacomiaella problematica* (Furlani), plant detritus, and foraminifers *Haplophragmoides* sp., *Ammobaculites* sp., *Charentia evoluta* (Gorb.), *Stomatostoecha compressa* Gorb., *S. sp.*, *Pseudocyclamina lituus* (Yok.), *P. spharaedalis* Hott., *Anchispirocyclina lusitanica* (Egg.), *Spirillina kubleri* Mjatl., *Trocholina alpina* (Leup.), *T. burlini* Gorb., and *Epistomina ventriosa* Esp. et Sig. The thickness is 30 m.

Member 14: light gray limestone, massive to conglomeratic, is containing small subangular sandstone and limestone pebbles. The thickness is 2 m.

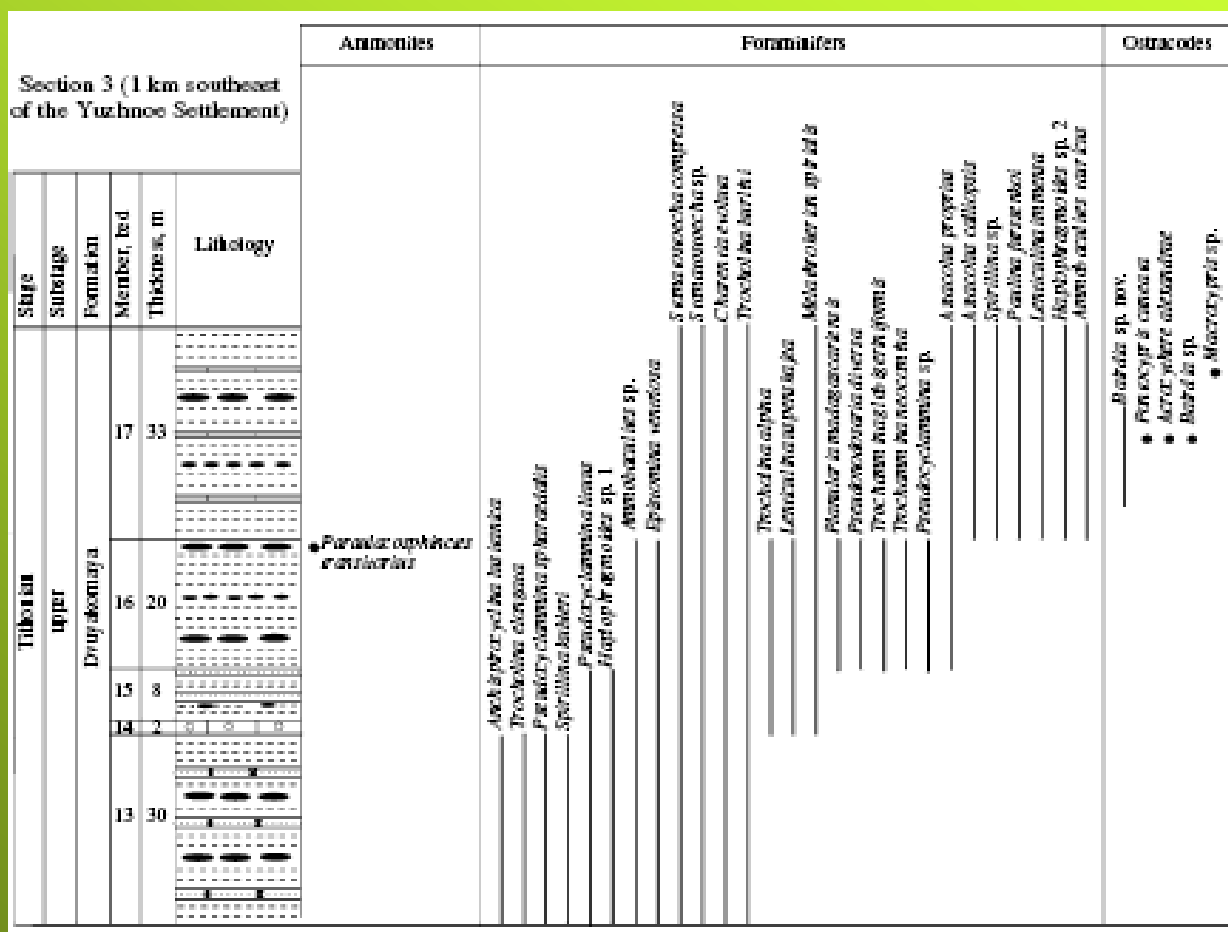


Figure 10CRI (Arkad'ev et al., 2006). Distribution of ammonites, foraminifers, and ostracodes in Section 3 (see Fig.10CRD for legend).

Member 15: dark greenish gray clay, fine-grained, splintery, is containing thin (5–10 cm) interbeds of gray sandstones and lenses of siderites with the brown surface. The member is crowned by a bed (0.5 m) of light gray massive fine- to medium-grained sandstone grading into brown siderite. The top plane of the bed is uneven, hummocky. Fossils are represented by foraminifers *Haplophragmoides* sp., *Melathrokerion spirialis* Gorb., *Charentia evoluta* (Gorb.), *Pseudocyclammina lituus* (Yok.), *Lenticulina uspenskajea* K. Kuzn., and *Trocholina alpina* (Leup.).

The thickness is 8 m.

Member 16: greenish gray clays, splintery, with siderite lenses and interbeds; a siderite lens in the uppermost part of the member yielded ammonite *Paraulacosphinctes transitorius* (Oppel).

The thickness is 20 m.

Member 17: dark gray clays, fine-grained, splintery, with interbeds (3–5 cm) of pinkish gray very compact cryptocrystalline limestones; hosting brown siderites lenses (up to 30 cm) occur as well. Foraminifers found in the member are *Ammobaculites* sp., *Melathrokerion spirialis* Gorb., *Charentia evoluta* (Gorb.), *Stomatostoecha compressa* Gorb., *S. sp.*, *Pseudocyclammina* sp., *Trochammina globigeriniformis* (Parker et Jones), *T. neocomiana* Mjatl., *Pseudonodosaria diversa* (Hoff.), *Lenticulina uspenskajea* K. Kuzn., *Astacolus proprius* K. Kuzn., *Planularia madagaskariensis* Esp. et Sig., *Trocholina burlini* Gorb., *T. alpina* (Leup.), and *Epistomina ventriosa* Esp. et Sig. The ostracode assemblage includes poorly preserved *Bairdia* sp. nov., *B. sp.*, *Pontocypris cuneata* Neale, *Acrocythere alexandrae* Neale et Kolp., and *Macrocypris* sp.

The thickness is 33 m.

The overlying sediments are much better exposed and studied in paleontological aspect in the Cape Svyatogo Il'i section (Fig. CR10J, Section 4). A thick (2.5 m) bed of conglomeratic limestones with angular and subrounded pebbles (up to 2–3 cm across) of limestone and other rocks is exposed immediately above the water level in a cliff 200 m west of the lighthouse. The upper boundary of the bed is sharp, eroded. Its uppermost part (10–15 cm) is true conglomerate, which yielded an echinoid plate and poorly preserved cast of ammonite *Haploceras* sp. Foraminifers *Pseudocyclammina spharaedalis* Hott., and *Anchispirocyclina lusitanica* (Egg.) are identified in thin sections. No other limestone beds of similar thickness have been observed in examined sections, and their correlation is problematic. Judging from the foraminiferal assemblage, this bed belongs still to the Tithonian Stage. Its upper erosional surface is overlain by the following members:

Tithonian/Berriasian boundary. Member 18: alternating clays (1.5–2.0 m) and limestones (0.10–0.15 m); dominant clays are greenish gray, compact, splintery, frequently soft with limonitized pyrite nodules and parallel bedding. Synsedimentary flattened clay pebbles are concentrated in places. Limestones are light gray to light brown, compact, detrital, lenticular in the lower part of the member; numerous fucoids are confined to bedding planes. Aptychi *Punctaptychus* aff. *malbosi* (Pict.) and *P.* aff. *Imbricatus* (Meyer) are found at the member base. Sediments 4 m higher contain diverse fossils: ammonites *Berriasella chomeracensis* (Touc.), *B.* sp., *Fauriella* cf. *floquinensis* Le Heg., *Ptychophylloceras* cf. *semisulcatum* (d'Orb.), *Haploceras* sp.; belemnite *Duvalia* sp.; bivalve *Amusium sokolovi* Ret.; brachiopod *Tonasirhynchia janini* Lobatsch. et Smirn.; aptychi *Punctaptychus punctatus rectecostatus* Cuzzi, *P. punctatus flactocostatus* Trauth., *P. imbricatus* (Meyer), *P.* cf. *monsalsvensis* Trauth, and *P. malbosi* (Pict.). The very diverse foraminiferal assemblage consists of *Reophax* sp., *Haplophragmoides* cf. *vocontianus* Moull., *H.* sp. 1, *H.* sp. 2, *Ammobaculites inconstans inconstans* Bart. et Brand, *A. inconstans gracilis* Bart. et Brand, *A.* cf. *Eocretaceous* Bart. et Brand, *A.* sp. 1, *A.* sp. 2, *Triplasia emsladensis acuta* Bart. et Brand, *Melathrokerion spirialis* Gorb., *M.* sp., *Charentia evoluta* (Gorb.), *C.* sp., *Stomatostoecha enisalensis* Gorb., *S. rotunda* Gorb., *S. compressa* Gorb., *Pseudocyclammina lituus* (Yok.), *P.* sp., *Everticyclammina* sp., *Rectocyclammina* sp., *Textularia crimica* (Gorb.), *T.* sp., *Trochammina* sp., *Dorothia* sp., *Quinqueloculina* sp., *Isytriloculina* sp. 1, *I.* sp. 2, *Nodosaria paupercula* Reuss, *N. Sceptum* Reuss, *N.* sp., *Pseudonodosaria diversa* (Hoff.), *P. Humulis* (Roem.), *P. mutabilis* (Reuss), *Fronicularia* sp., *Lenticulina* cf. *ambanjabensis* Esp. et Sig., *L. neocomiana* Rom., *L. macra* Gorb., *L. ex gr. gutata* (ten Dam), *L. nimbifera* Esp. et Sig., *L. colligoni* Esp. et Sig., *L.* sp. 1, *L.* sp. 2, *Astacolus laudatus* (Hoff.), *A.* cf. *favoritus* Gorb., *A. calliopsis* (Reuss), *A. planiusculus* (Reuss), *A.* sp., *Planularia crepidularis* Roem., *Dentalina nana* Reuss, *Spirillina kubleri* Mjatl., *S.* sp., *Globospirillina neocomiana* (Moull.), *G. caucasica* (Hoff.), *Miliospirella* cf. *caucasina* Ant., *Trocholina elongata* (Leup.), *T. alpina* (Leup.), *T. giganta* Gorb. et Manz., *T. molesta* Gorb., *T. burlini* Gorb., *Discorbis crimicus* Schok., *Siphoninella antiqua* Gorb., *Epistomina* cf. *ornota* (Roem.), *E. caracolla caracolla* (Roem.), *Protopeneroplis ultragranulatus* (Gorb.), *Pseudolamarckina* sp., *Conorotalites ex gr. bartensteni* (Bett.), *Ticinella roberti* Gand. Similarly diverse is also the ostracode assemblage: *Bairdia* sp. nov., *B.* sp. nov. 1, *Tethysia chabrensis* Donze,

Cytherelloidea mandelstami blanda Neale, *C. flexuosa* Neale, *Acrocythere aspera* Donze, *A. cf. aspera* Donze, *A. alexandrae* Neale et Kolp., *Cytherella cf. krimensis* Neale et Kolp., *C. lubimovae* Neale, ?*Mandocythere (Costacythere) frankei* (Trieb.), “*Orthonatacythere*” sp. nov., “*O.*” sp. nov. 1, *Prodeucythere eocretacea* Neale et Kolp., *Eucytherura ardescae* Donze, “*Cytherura*” sp. nov., ?*Clitocytheridea paralubrica* Neale et Kolp., *Palaeocytheridella teres* Neale, *Macrocypris* sp. B Neale, ?*Neocythere* sp., and others.

The thickness is 16.6 m.

Member 19: light green clays intercalated with centimeters-thick laminae of light brown compact detrital limestones with abundant fucoids. Foraminiferal assemblage consists of *Reophax* sp., *Ammobaculites inconstans inconstans* Bart. et Brand, *A. sp.*, *Melathrokerion spirialis* Gorb., *Charentia evoluta* (Gorb.), *C. sp.*, *Stomatostoecha compressa* Gorb., *Trochammina* sp., *Isytriloculina* sp. 2, *Lenticulina cf. ambanjabensis* Esp. et Sig., *L. neocomiana* Rom., *L. macra* Gorb., *L. ex gr. gutata* (ten Dam), *Spirillina kubleri* Mjatl., *Globospirillina neocomiana* (Moull.), *Discorbis crimicus* Schok., and *Epistomina caracola caracola* (Roem.). Ostracodes are represented by *Bairdia* sp. nov., *Acrocythere aspera* Donze, *A. cf. aspera* Donze, *A. alexandrae* Neale et Kolp., *Tethysia chabrensis* Donze, *Cytherelloidea mandelstami blanda* Neale, *Cytherelloidea* sp. 2, *Cytherella krimensis* Neale, *Cythereis* aff. *senckenbergi* Trieb., *Prodeucythere eocretacea* Neale et Kolp., *Pontocypris* aff. *arcuata* Lub., *Schuleridea juddi* Neale, “*Orthonatacythere*” sp. nov. 1, *Procytherura* sp., “*Bythocypris*” sp., and others.

The thickness is 8 m.

Member 20: alternating greenish gray splintery clays (dominant, 2–3 m thick) and light brown compact detrital limestones (0.3–0.5 m, mainly in the middle part of the member); the uppermost part encloses interbeds (0.1–0.2 m) of dark gray and dark green parallel-bedded marls. The marls contain various fossils:

ammonites *Haploceras cf. carachtheis* (Zeus.), *H. sp.*; aptychi *Punctaptychus cf. punctatus* (Voltz), *P. cf. malbosi* (Pict.), *P. cf. imbricatus* (Meyer); foraminifers *Ammobaculites* sp., *Stomatostoecha enisalensis* Gorb., *Rectocyclammina* sp., *Feurtilia frequensis* Maync, *Pseudocyclammina lituus* (Yok.), *Textularia crimica* (Gorb.), *Nodosaria sceptrum* Reuss, *Trochammina* sp., *Dorothia* sp., *Sigmoilina* sp., *Pseudonodosaria mutabilis* (Reuss), *Lenticulina neocomiana* Rom., *L. macra* Gorb., *L. sp. 1*, *Astacolus cf. favoritus* Gorb., *A. calliopsis* (Reuss), *A. planiusculus* (Reuss), *A. laudatus* (Hoff.), *A. proprius* K. Kuzn., *Saracenaria latruncula* (Chal.), *Spirillina kubleri* Mjatl., *Miliospirella cf. caucasina* Ant., *Trocholina alpina* (Leup.), *T. gigantea* Gorb. et Manz., *T. molesta* Gorb., *Discorbis crimicus* Schok., *Epistomina cf. ornata* (Roem.), *Protopeneroplis ultragranulatus* (Gorb.); ostracodes *Bairdia* sp. nov., *B. sp. nov. 1*, *Acrocythere aspera* Donze, *Cytherella krimensis* Neale, *C. lubimovae* Neale, *Cytherelloidea mandelstami blanda* Neale, *C. mandelstami mandelstami* Neale, *C. flexuosa* Neale, *Cythereis* aff. *senckenbergi* Trieb., “*Cytherura*” sp. nov., *Eucytherura ardescae* Donze, “*Orthonatacythere*” sp. nov. 1, *Protocythere revili* Donze, *Procytheropteron barkeri* And., *Pontocypris cuneata* Neale, *Macrocypris* sp., ?*Neocythere* sp., and others.

The thickness is 17 m.



Member 21: greenish gray splintery clays with rare interbeds (0.10–0.15 m) of cream-colored detrital limestones; in the middle, there is a thick (0.8 m) limestone bed with abundant rounded pebbles at bedding surfaces. Sediments yield ostracodes *Bairdia* sp. nov., *B.* sp. nov. 1, *Eucytherura ardescae* Donze, *Cytherella krimensis* Neale, *Protocythere revili* Donze, *Raymoorea peculiaris* (Donze), *?Rhinocypris jurassica* (Mand.), *?Clitocytheridea paralubrica* Neale et Kolp., and others.

The thickness is 10 m.

Member 22: bluish gray platy clays with subordinate interbeds (0.5–0.6 m) of dark brown massive detrital limestones. Sediments contain foraminifers *Reophax* sp., *Ammobaculites* sp. 1, *Haplophragmoides* cf. *vocontianus* Moull., *H.* sp., *Stomatostoecha enisalensis* Gorb., *S. Compressa* Gorb., *Everticyclammina* sp., *Pseudocyclammina* sp., *Trochammina* sp., *Nodosaria paupercula* Reuss, *N.* sp., *Lenticulina nimbifera* Esp. et Sig., *L.* sp. 2, *Astacolus laudatus* (Hoff.), *A.* sp., *Spirillina kubleri* Mjatl., *Trocholina alpina* (Leup.), *T. gigante* Gorb. et Manz., and *T. molesta* Gorb.

The thickness is 13 m.

Member 23: yellowish gray splintery clays (1.0–1.5 m) enclosing six interbeds of yellowish gray platy marls (0.5– 0.8 m); marls sandy, thin-platty in the lower part of the member are thicker and calcareous in the upper part. All the marl interbeds contain ammonites, aptychi forms, rare brachiopods, foraminifers, ostracodes, and abundant fucoids. Ammonites are represented by *Ptychophylloceas* sp. in the lowest marl bed, by *Delphinella* sp., *Biasaloceras liebigi* (Opp.) in the third bed from below, and by *Delphinella crimense* (Burck.) *Retowskiceras* sp., *Pseudosubplanites* sp., *Holcophylloceras tauricum* (Ret.), *Protetragonites tauricus* (Kulj.-Vor.), *Ptychophylloceas* sp. in the fourth bed. In the fifth marl bed, *Pseudosubplanites ponticus* (Ret.), *P. lorioli* (Zitt.), *P. combesi* Le Heg., *Haploceras carachtheis* (Zeusc.), *Ptychophylloceas semisulcatum* (d'Orb.), *Protetragonites tauricus* (Kulj.-Vor.), and *Biassaloceras* sp. occur in association with brachiopod *Tonasirhynchia janini* Lobatsch. et Smirn. Characteristic of the sixth marl bed are *Pseudosubplanites grandis* (Maz.), *P. lorioli* (Zitt.), *Delphinella* cf. *crimense* (Burck.), *Ptychophylloceas semisulcatum* (d'Orb.) associated with aptychus *Punctaptychus punctatus* (VOLTZ). Ammonites *Delphinella* sp., *Retowskiceras* sp., *Tirnovella* sp., *Biasaloceras* sp., *Spiticeras* sp., and aptychus *Punctaptychus cinctus* Trauth. are found in talus derived from Member 23. The lower part of the member hosts foraminifers *Reophax gigantius* A.-V., *Haplophragmoides* sp., *Ammobaculites eocretaceous* Bart. et Brand, *A. inconstans gracilis* Bart. et Brand, *A.* sp. 1, *Melathrokerion* sp., *Charentia* sp., *Stomatostoecha rotunda* Gorb., *Textularia crimica* (Gorb.), *Dorothia pseudocostata* (Ant.), *D.* sp. 1, *D.* sp. 2, *Pseudonodosaria humulis* (Roem.), *P. diversa* Reuss, *P.* sp., *Fronicularia cuspidata* Pathy, *Lenticulina* ex gr. *gutata* (ten Dam), *L.* cf. *postuhlidi* K. Kuzn., *Astacolus* cf. *favoritus* Gorb., *A. planiusculus* (Reuss), *A. proprius* K. Kuzn., *A.* sp., *Planularia madagaskariensis* Esp. et Sig., *Saracenaria latruncula* (Chal.), *S. inflanta* Pathy, *Dentalina marginulina* Reuss, *D.* sp., *Spirillina kubleri* Mjatl., *S.* sp.,

Globospirillina caucasica (Hoff.), *Trocholina elongata* (Leup.), *T. molesta* Gorb., *Epistomina caracolla caracolla* (Roem.), and *Conorotalites* ex gr. *bartensteni* (Bett.). Foraminiferal assemblage from the upper part is inherited partly from underlying sediments. It includes *Haplophragmoides* sp. 1, *Triplasia* sp., *Charentia evoluta* (Gorb.), *Pseudocyclammina* sp., *Textularia* sp., *Sigmoilina* sp., *Nodosaria sceptrum* Reuss, *Astacolus calliopsis* (Reuss), *A. planiusculus* (Reuss), *Planularia madagascariensis* Esp. et Sig., *Dentalina nana* Reuss, *Globospirillina neocomiana* (Moull.), *Trocholina alpina* (Leup.), *T. gigante* Gorb. et Manz., *T. molesta* Gorb., *T. burlini* Gorb., *Discorbis crimicus* Schok. and *Textularia crimica* (Gorb.) much more abundant than below. Species first appearing in the assemblage are *Belorussiella taurica* Gorb., *Lingulina trilobitomorpha* Pathy, *Citharina paucicostata* (Reuss), and *Nautiloculina oolitica* Moch. Concurrent ostracodes are represented by *Bairdia* sp. nov., *B.* sp. nov. 2, *Acrocythere aspera* Donze, *A. alexandrae* Neale et Kolp., *Pontocyprilla superba* Neale, *P. elongata* Kub., *Tethysia chabrensis* Donze, *Cytherella krimensis* Neale, “*Cytherura*” sp. nov., *Eucytherura ardescae* Donze, *Protocythere revili* Donze, *Mandocythere foveata* Tes. et Rach., *Prodeucythere eocretacea* Neale et Kolp., *Pontocypris* aff. *arcuata* Lub., *Palaeocytherida baculumbajula* (Mand.), *?Neocythere* sp., and others.

The thickness is 13 m.

The integral thickness of the Dvuyakornaya Formation in the examined sections is 360 m. Being determined in dismembered succession, the formation is likely incomplete. It is divisible in two parts of different lithology. The lower part (sections 1–3) is largely composed of clays with subordinate sandstone interbeds and abundant siderite concretions. The upper part (Section 4) is characterized by thin flyschoid alternation of clays and limestones. The uppermost part includes the “Feodosiya Marl” (Member 23 in Section 4). This member is traceable from the Cape Svyatogo Il’i along the Dvuyakornaya Bay shore for a distance of approximately 2 km to become unexposed northward. The same member is also exposed in the Berriasian sections near the Yuzhnoe and Nanikovo settlements in western outcrops of the study area. Retaining its lithological and paleontological properties, the member can be regarded as a stratigraphic marker.

Interpretation - The data obtained make can be used to reconstruct sedimentation environments in the late Kimmeridgian–Berriasian basin of the eastern Crimea. *Flyschoid bedding (with prevalence of clays over limestones) and almost complete absence of benthic macrofossils* are characteristic of the relevant sediments. Faunal remains are represented mainly by rare nektonic forms (ammonites, belemnites) and numerous benthic foraminifers and ostracodes. *Up to 90% studied foraminifers and ostracodes bear signs of transportation.* In addition, the lower part of the section contains pseudoplanktonic bivalves belonging to the genus *Bositra*. Limestones are lumpy, oolitic (of the grainstone type), detrital. In central parts of oolites, there are fragments of foraminiferal tests, ostracode carapaces, angular and subangular quartz grains. Frequently, oolites develop after limestone clasts. Detrital (conglomeratic) limestones include fragments of fine-grained limestones up to several centimeters across. Clays of the Dvuyakornaya Formation are kaolinite–hydromicaceous, usually laminated. Sediments show presence of slumping structures. *All the mentioned features suggest accumulation of these sediments below the waves base level, i.e., outside the shelf. Sediments of this kind accumulate at depths ranging from 300–400 m to 1–3 km. Conglomeratic limestones of the Dvuyakornaya Formation should probably be considered as rocks originated by redeposition of shallow-water carbonate material on the continental slope by debris flows.* This

This is also evident from slumping structures and mostly rounded foraminiferal tests and ostracode carapaces. The suggested deep-water sedimentation in the Tithonian–Berriasian basin of the eastern Crimea is well consistent with the general paleogeographic situation of that time. In the Jurassic–Early Cretaceous, epicontinental shelf seas with carbonate sedimentation of the Scythian and Turan plates sharply decreased in size. Deep-water sediments of the Dvuyakornaya Formation formed likely on the continental slope at depths of several hundreds meters or deeper near the narrow shelf of the Scythian plate. This part of the Tethys was characterized by high water temperatures (22–24°C), normal salinity, and Mediterranean fauna with relatively small quantity of endemic species. In the north, the basin was separated by a lowland from the sea covering the Russian plate.

Structure: First Muratov who studied in detail geological structure of the eastern Crimea defined the Feodosiya block consisting of the Teteobinskaya, Sultanovka, and Dvuyakornaya synclines in the schematic tectonic map of the region. In terms of the present-day tectonic concept, the study area is a part of the Ortasyrt nappe, and the Dvuyakornaya Bay area corresponds to the Teteobinskaya allochthon (Fig. CR10A). The Upper Jurassic–Berriasian flyschoid clay–carbonate rocks of the allochthon are deformed into folds of different amplitude and size, which are complicated by faults. The faults are hardly detectable in clayey rocks, and thickness of the Dvuyakornaya Formation was overestimated probably because of this situation. Initially the formation estimated to be 800 m thick, but according to data Arkad'iev et al., 2006 the unit is only 360 m thick. The formation beds dip northeast in general under angles of 20–30°. With such an attitude, oldest layers of the formation are exposed in the southern limb of the Teteobinskaya allochthon; youngest strata in its northern limb within the Cape Svyatogo Il'i area.

Regional significance: The unique relatively complete section with abundant fossils containing Jurassic (Tithonian)/Cretaceous (Berriasian) boundary. These deposits are a good trace-marker within the Feodosiya region of the Eastern Crimea. This validation point is located at the Eastern-Crimean synclinorium

Petroleum systems information: No data

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



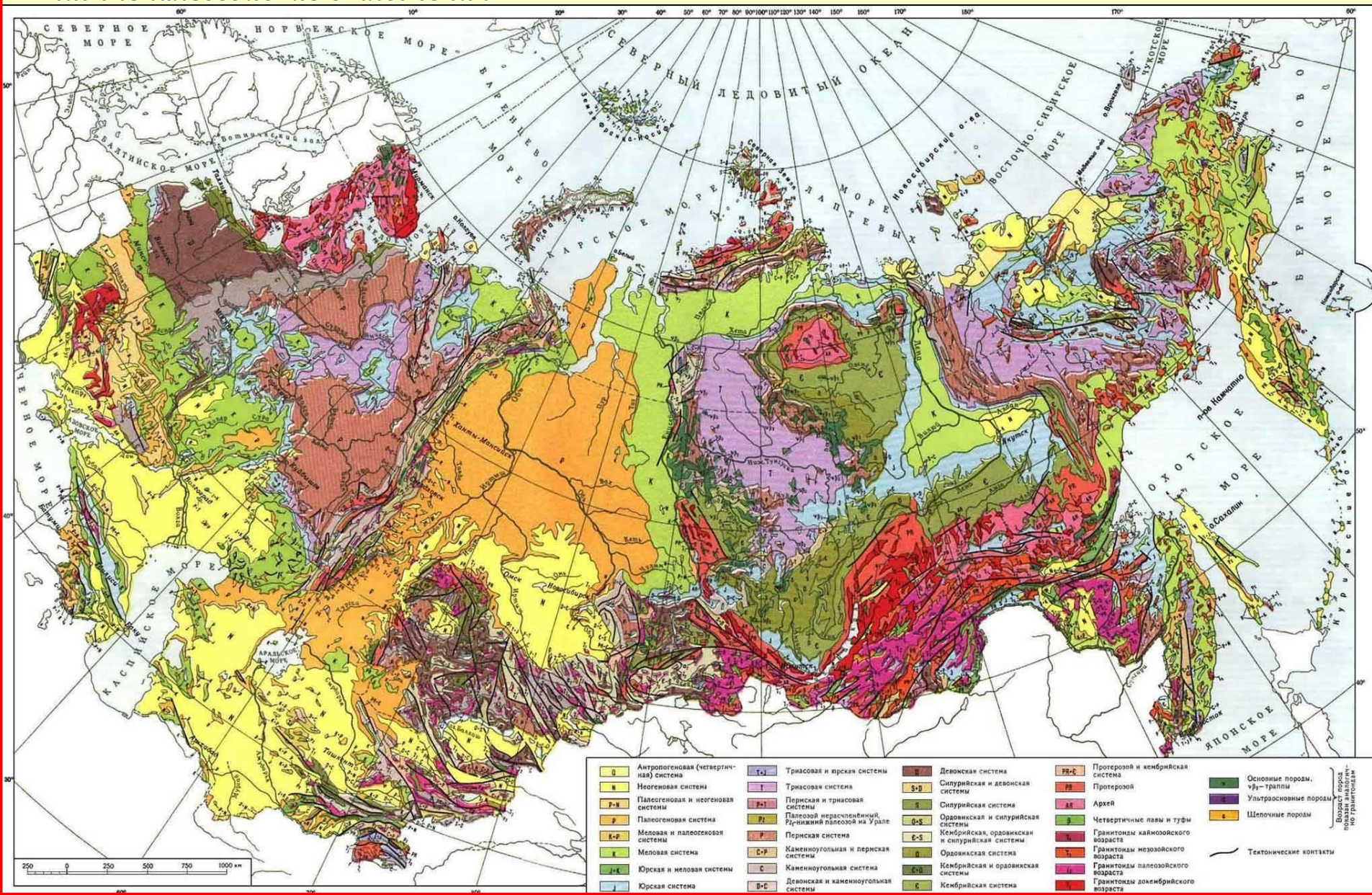
План лекции:

1. Общие представления о геологическом строении и развитии Восточно-Сибирской платформы

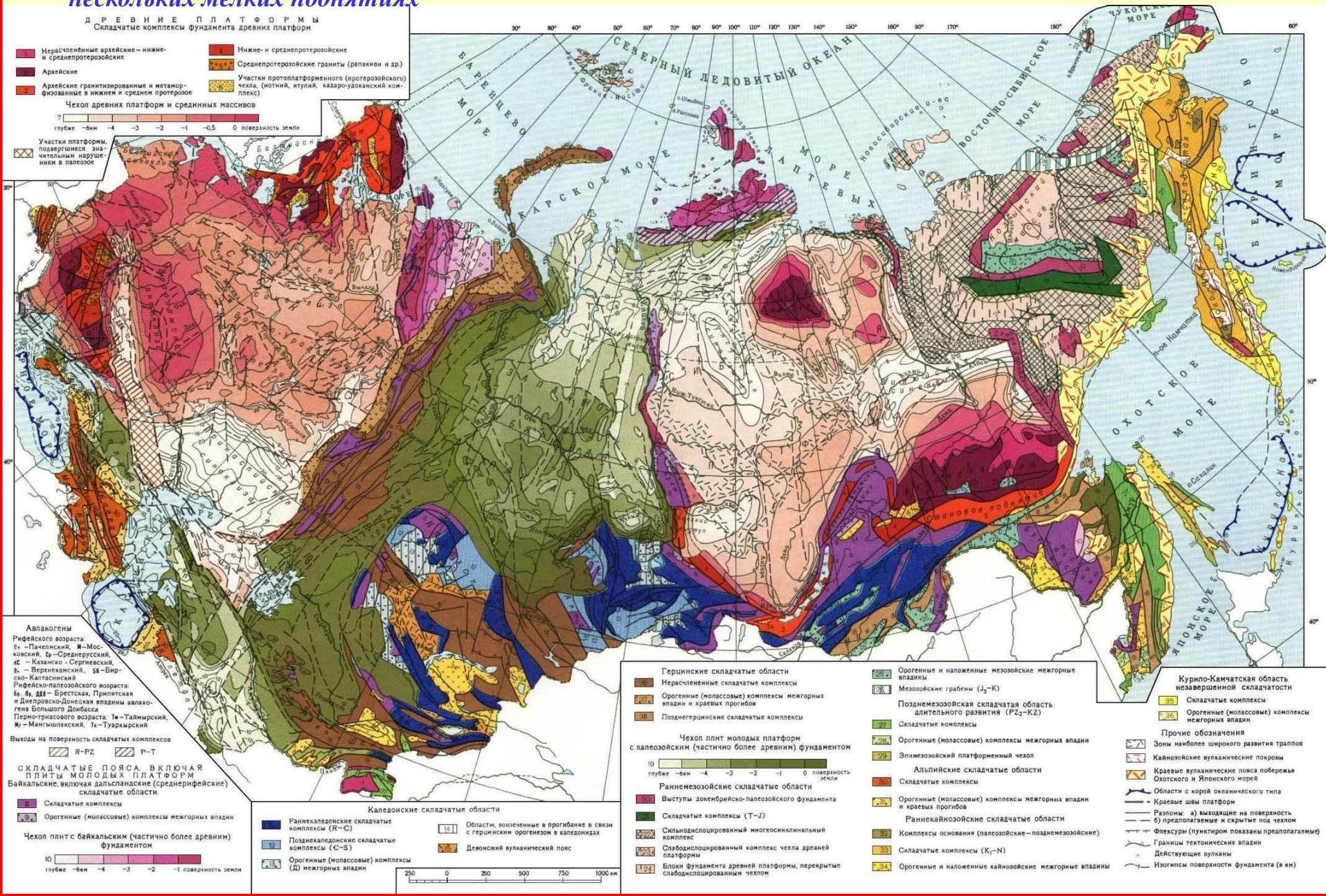
2. Примеры месторождений нефтегазоносных бассейнов Восточно-Сибирской платформы

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

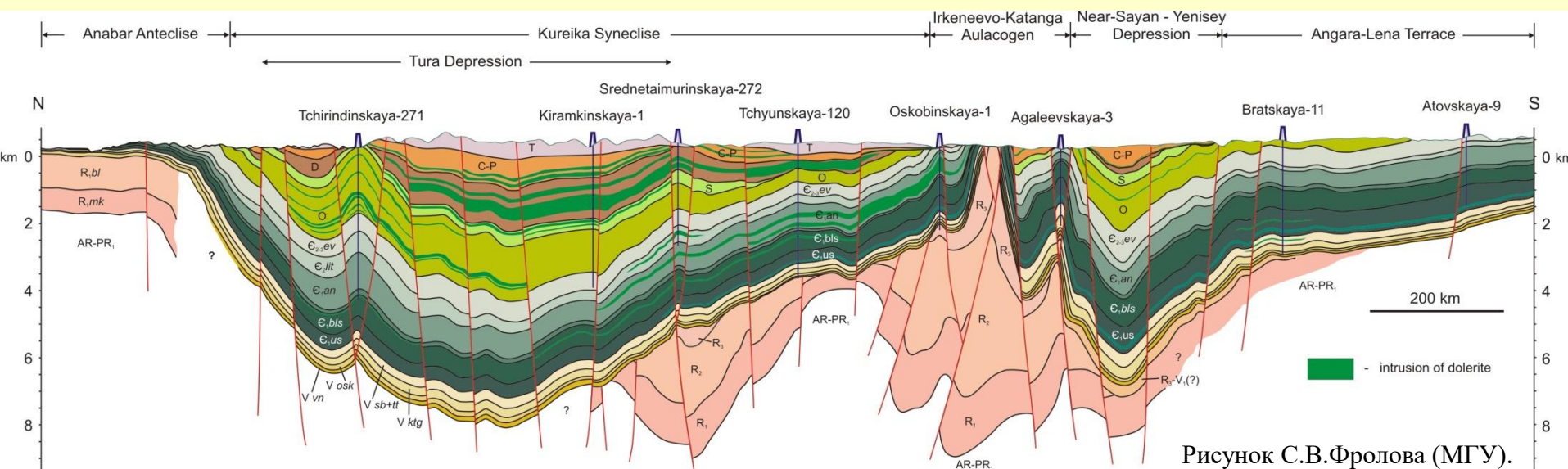
Общая площадь – 4 млн. км². Основная часть осадочного чехла – верхнепротерозойские и нижнепалеозойские отложения



Фундамент – архей-ранний протерозой, обнажается на Анабарском, Алданском щитах и на нескольких мелких поднятиях



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



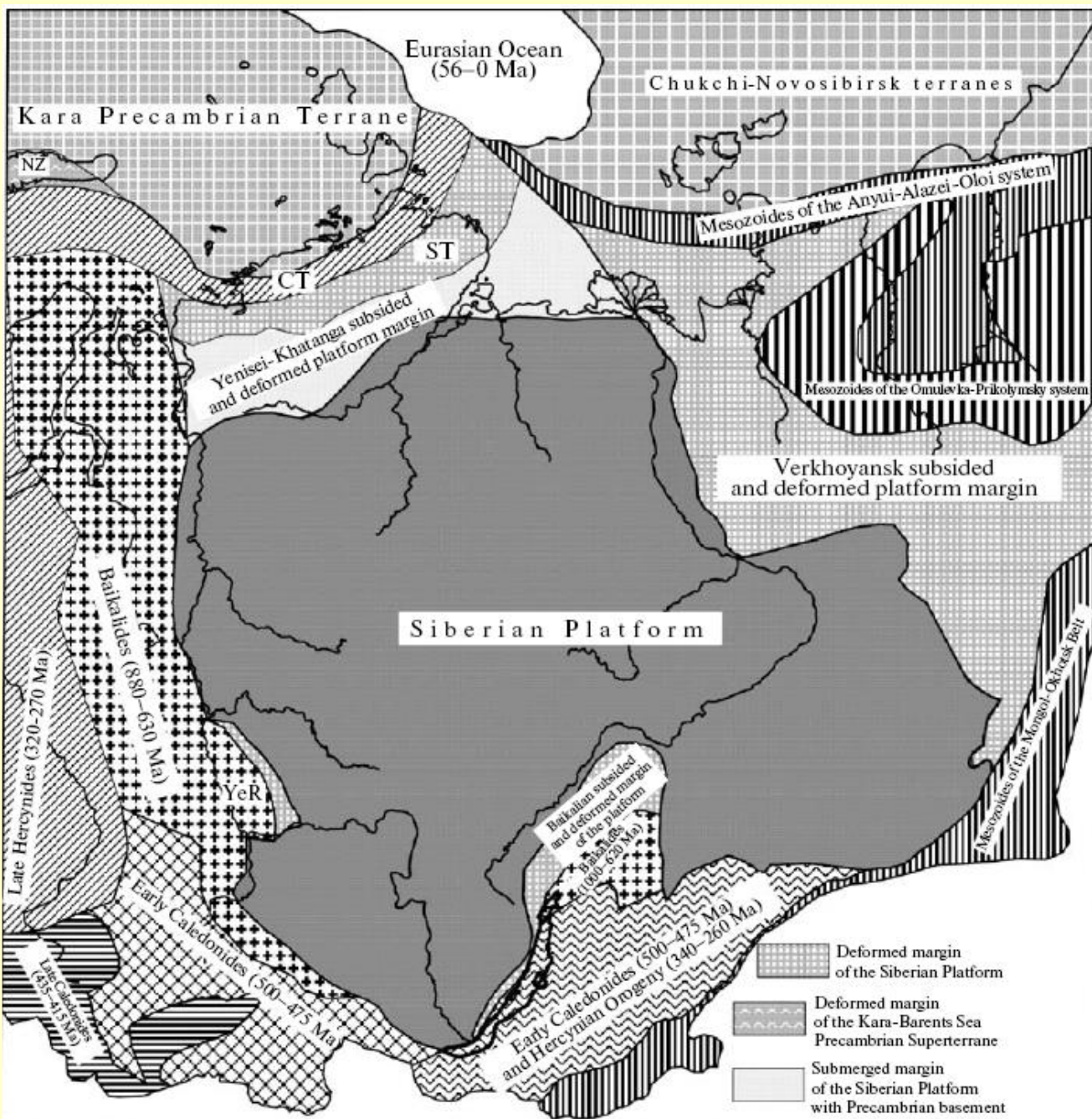
Разрез осадочного чехла центральных районов Восточно-Сибирской платформы изучен крайне неравномерно.

Рифейские и вендские комплексы глубоким бурением наиболее полно охарактеризованы в пределах Непско-Ботубинской антеклизы, Юрубчено-Тахомской зоны Байкитской антеклизы, а также в Катангской седловине. В естественных обнажениях разрезы рифея описаны на Енисейском кряже и на склонах Анабарской антеклизы.

Средне-верхнепалеозойские, а также триасовые отложения распространены в основном в пределах крупных депрессий (например, в Туринской синеклизе и Предпатомском прогибе).

Каменноугольно-пермские угленосные отложения слагают обширную Тунгусскую синеклизу, частично наложенную на раннепалеозойскую Туринскую (Фролов С.В., МГУ).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



Никишин и др, 2010 (Никишин А.М.,
Соборнов К.О., Прокофьев А.В., Фролов С.В.
Тектоническая история Сибирской
платформы в венде-фанерозое // Вестник
МГУ. Серия 4. Геология. 2010. № 1. С. 3-16.

Восточная Сибирь: структурное районирование

Структурные элементы, обозначенные на карте цифрами:

1—3 — Алдано-Становой щит: 1 — Алданское сводово-глыбовое поднятие, 2 — Становое сводово-глыбовое поднятие, 3 — Северо-Становая зона разломов; 4 — Учурская (Улканская) впадина; 5 — Маймаканское (Батомгское) поднятие; 6 — Суянагинский горст; 7 — Чульманская впадина; 8 — Токинская впадина; 9 — Чарская впадина (грабен); 10 — Алданская моноклизия; 11 — Учуро-Майская ступень; 12 — Юдомо-Майская впадина; 13 — Нельканская зона краевых дислокаций; 14 — Вилюйская синеклиза; 15 — Якутское сводовое поднятие; 16 — Нижнеалданская наложенная впадина; 17 — Байкальская область; 18 — Сунтарский горст; 19 — Уринский авлакоген; 20 — Байкало-Патомская складчатая зона; 21 — Нюйский прогиб; 22 — Березовский прогиб; 23 — Кемпендйская грабенообразная впадина; 24 — Мархинская (Ыгыатгинская) грабенообразная впадина; 25 — Лунгхинская впадина; 26 — Линденская впадина; 27 — Хапчагайский выступ; 28 — Предверхоанский краевой прогиб; 29 — Анабарский свод с выступом дорифейского фундамента; 30 — Оленекский свод; 31 — Котуйский авлакоген; 32 — Уджинский авлакоген; 33 — Хастахский авлакоген; 34 — Кютюнгинский грабен; 35 — Мунский свод; 36 — Суханская впадина; 37 — Ботуобинская седловина; 38 — Попигайская кольцевая структура (астроBLEMA?); 39—41 — Ангаро-Ленская ступень (39 — Прибайкальский прогиб; 40 — Непско-Присаянская зона; 41 — Непский свод (Непско-Ботуобинская антеклизия)); 42 — Иркутско-Черемховская впадина; 43 — Тасеевская синеклиза; 44 — Канская впадина; 45 — Иркинеевский авлакоген; 46 — Байкитская (Вельминская) антеклизия (46А — Камовский свод, 46Б — Бахтинский свод); 47 — Приенисейский прогиб; 48 — складчатое сооружение Енисейского кряжа; 49 — Тунгусская синеклиза; 50 — Курейская впадина; 51 — Ангаро-Вилюйский прогиб; 52 — Турухано-Норильский авлакоген; 53 — Игарская антиклинальная зона; 54 — Хантайско-Рыбинская антиклинальная зона; 55 — Енисейско (Пясино)-Хатангская впадина; 56 — Рассохинский вал; 57 — Балахнинский вал; 58 — Янгодо-Горбитский выступ; 59 — Лено-Хатангская впадина; 60 — Оленекская антиклинальная зона

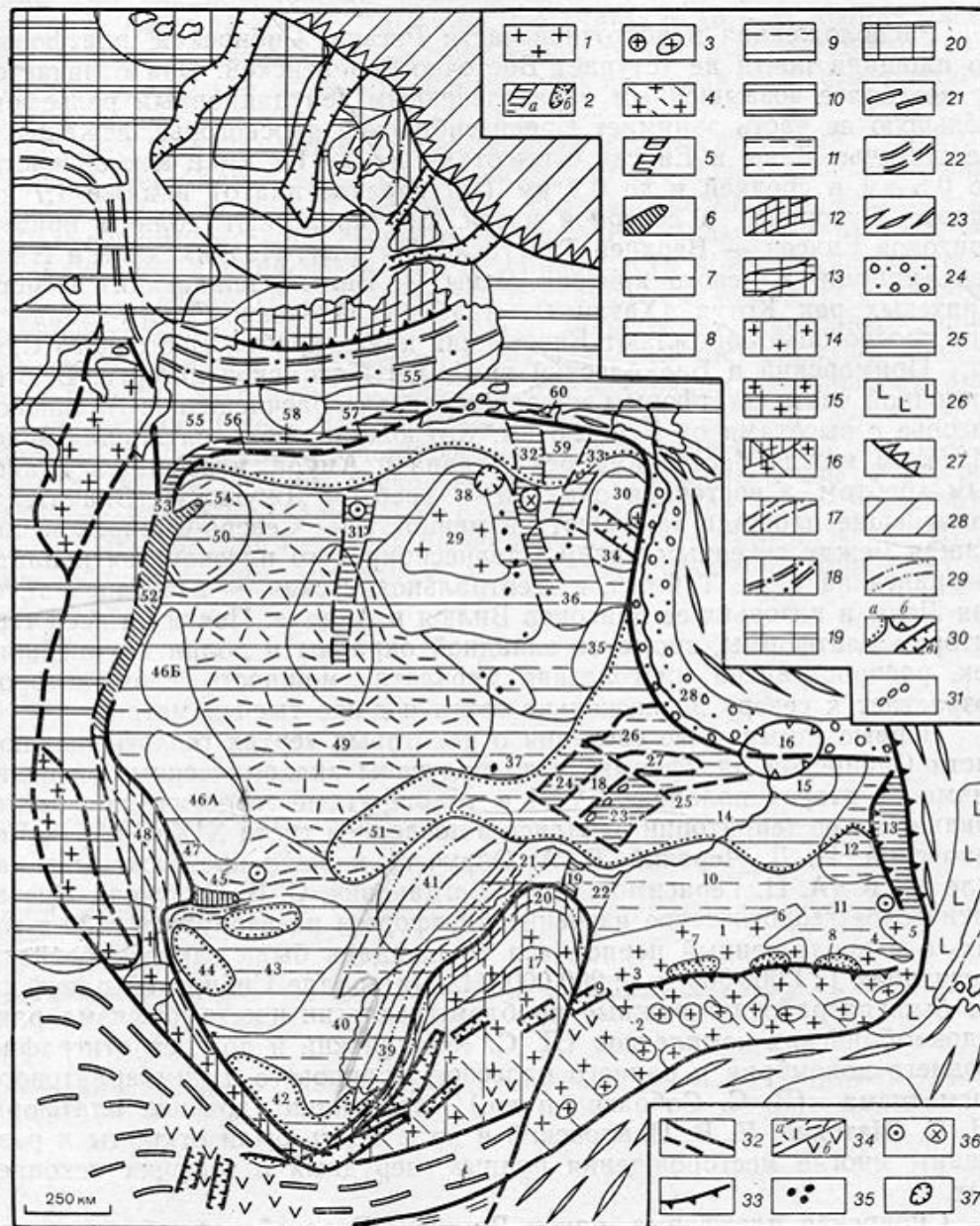


Рис. 1. Схема тектонического районирования Сибирской платформы и смежных метаттаплатформенных областей.

Восточная Сибирь: структурное районирование и НГБ

На северные и северо-восточные части наложены верхнепалеозойско-мезозойские прогибы.
58 месторождений нефти и газа, из них 10 крупных и 3 уникальных

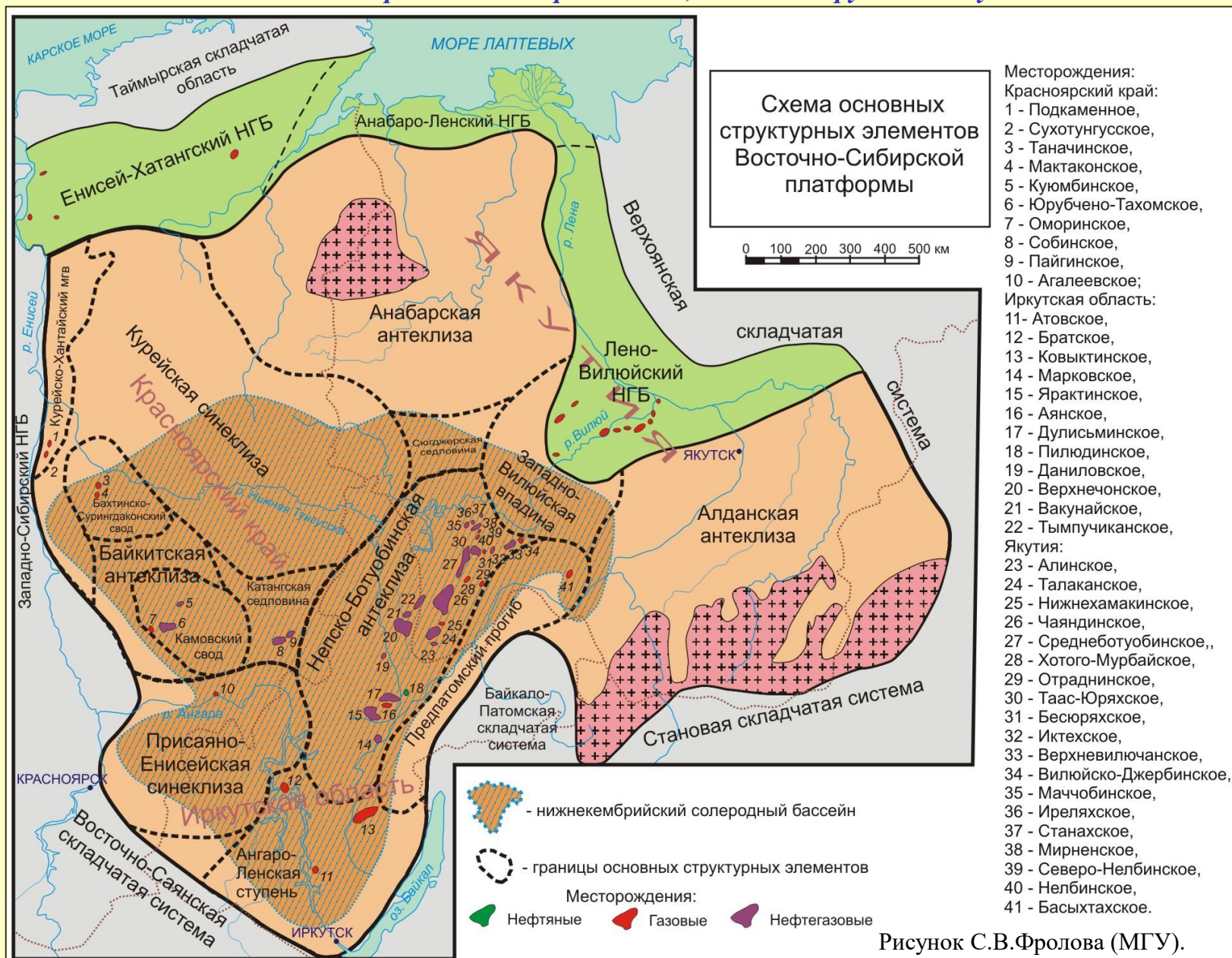
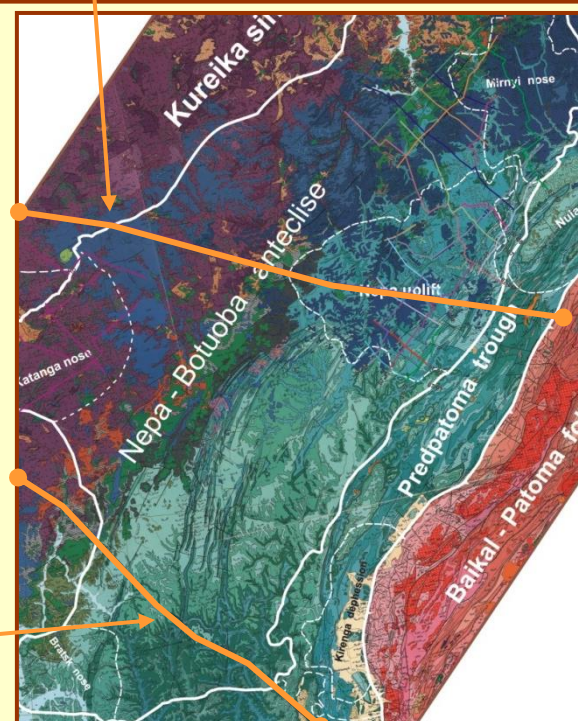
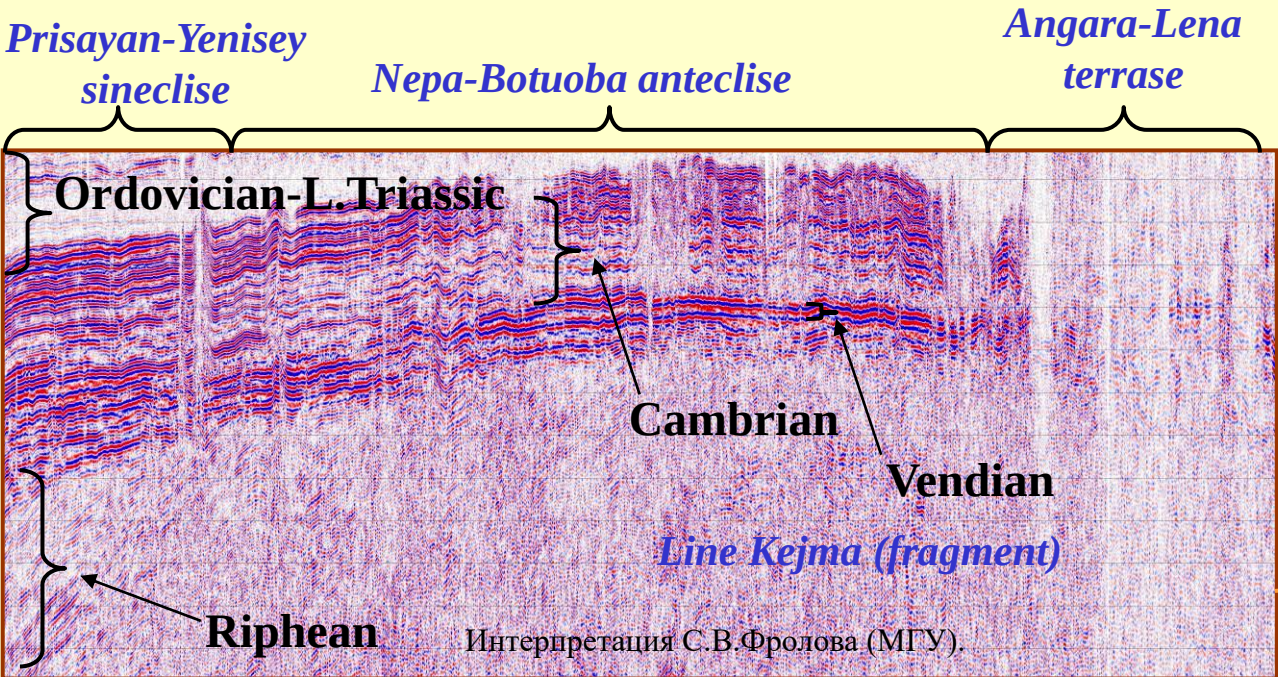
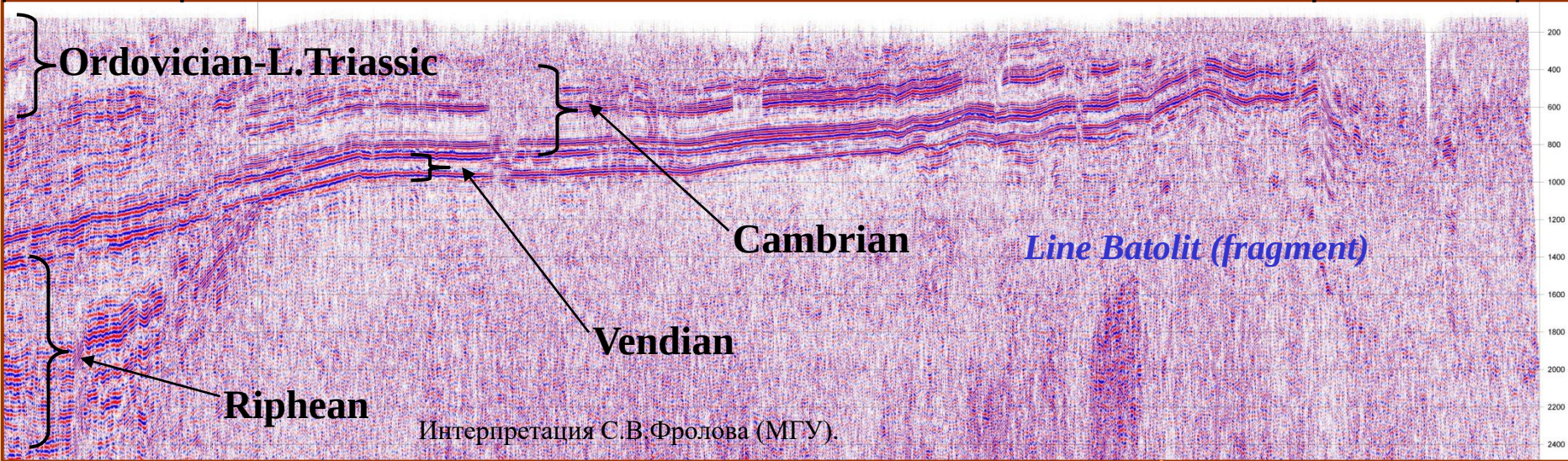


Рисунок С.В.Фролова (МГУ).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

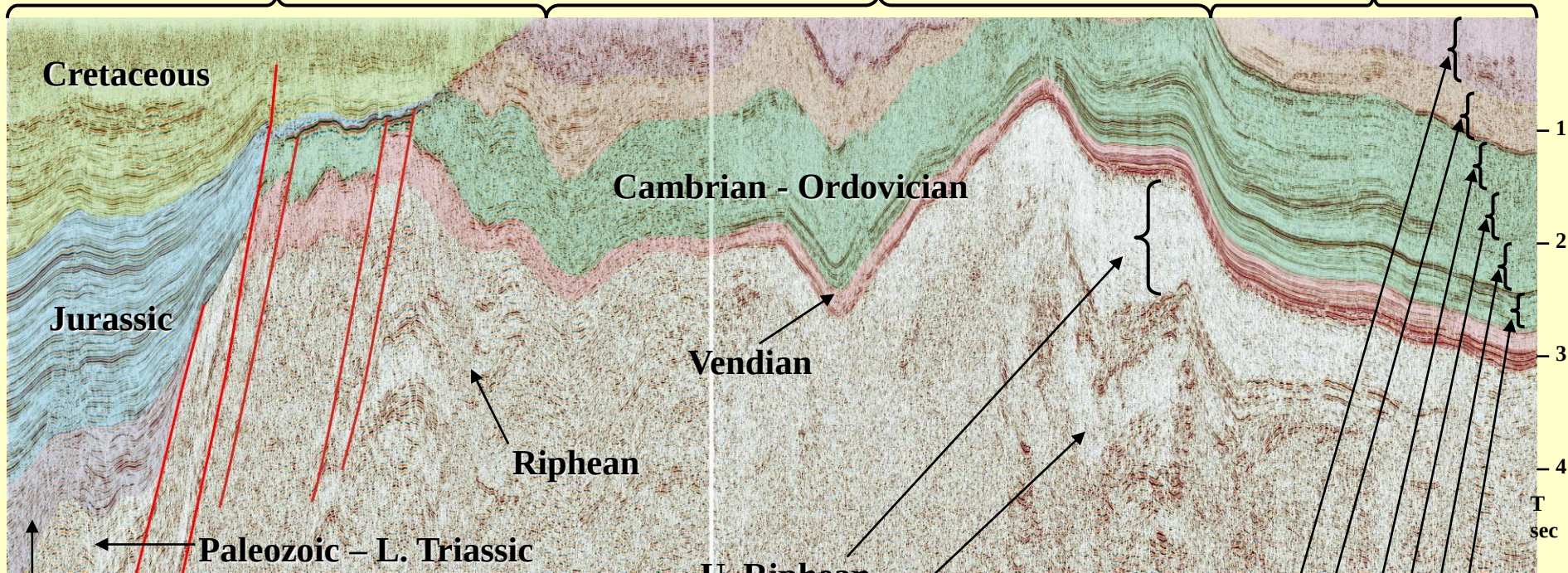


Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Yenisei – Khatanga trough

Turukhansk – Norilsk ridge

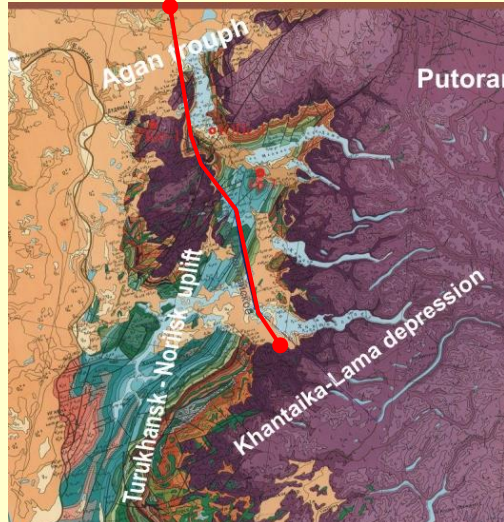
Kureika sineclise



M.–U. Triassic

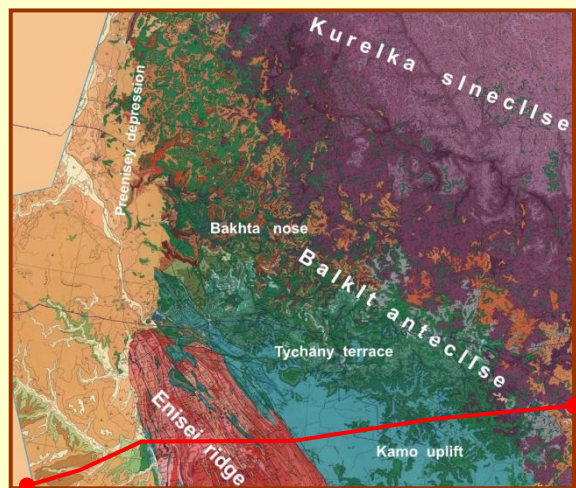
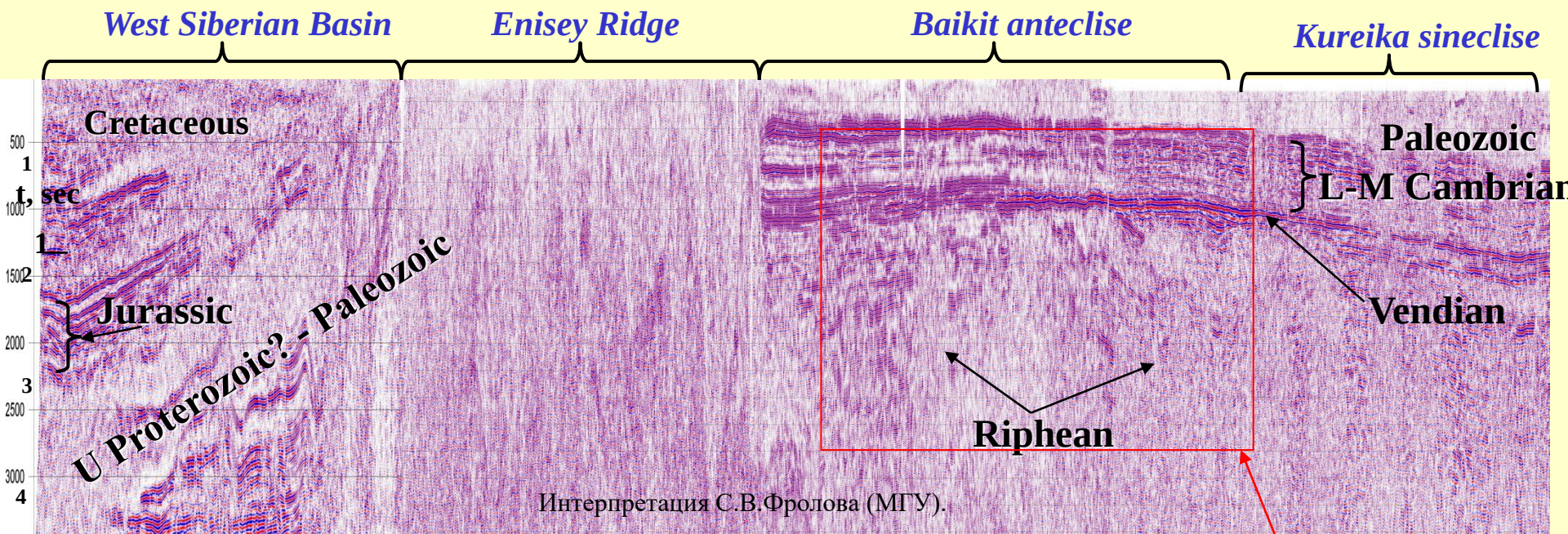
U. Riphean –
L. Vendian(?)
L.-M. Riphean

M. Carboniferous – L. Triassic
Silurian-L. Carboniferous
Ordovician
M.–U. Cambrian
L.-M. Cambrian
L. Cambrian

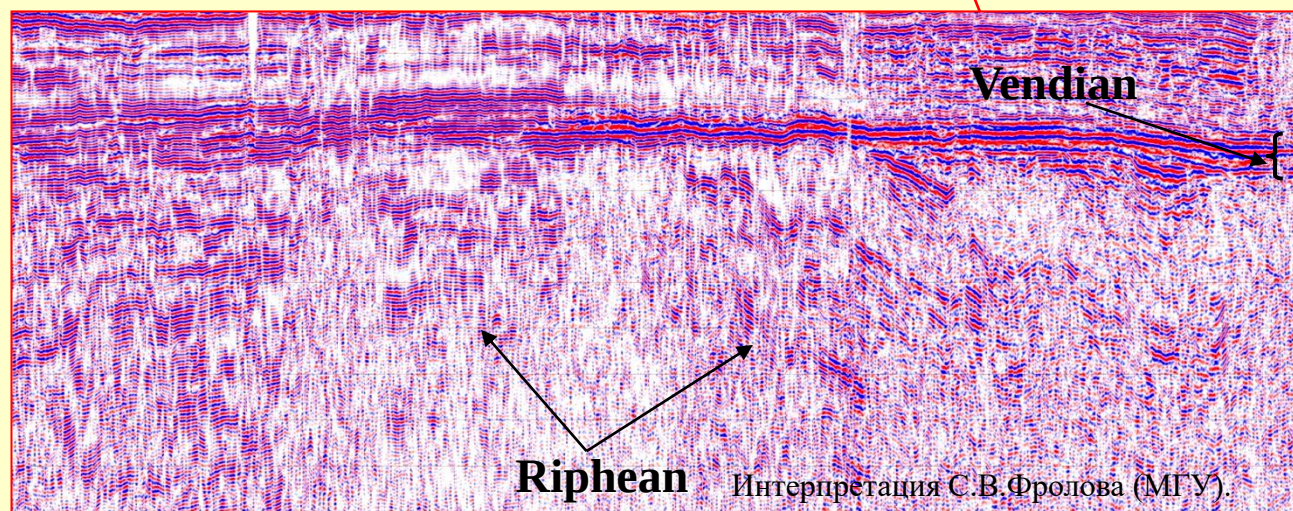


Северо-Западная часть

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



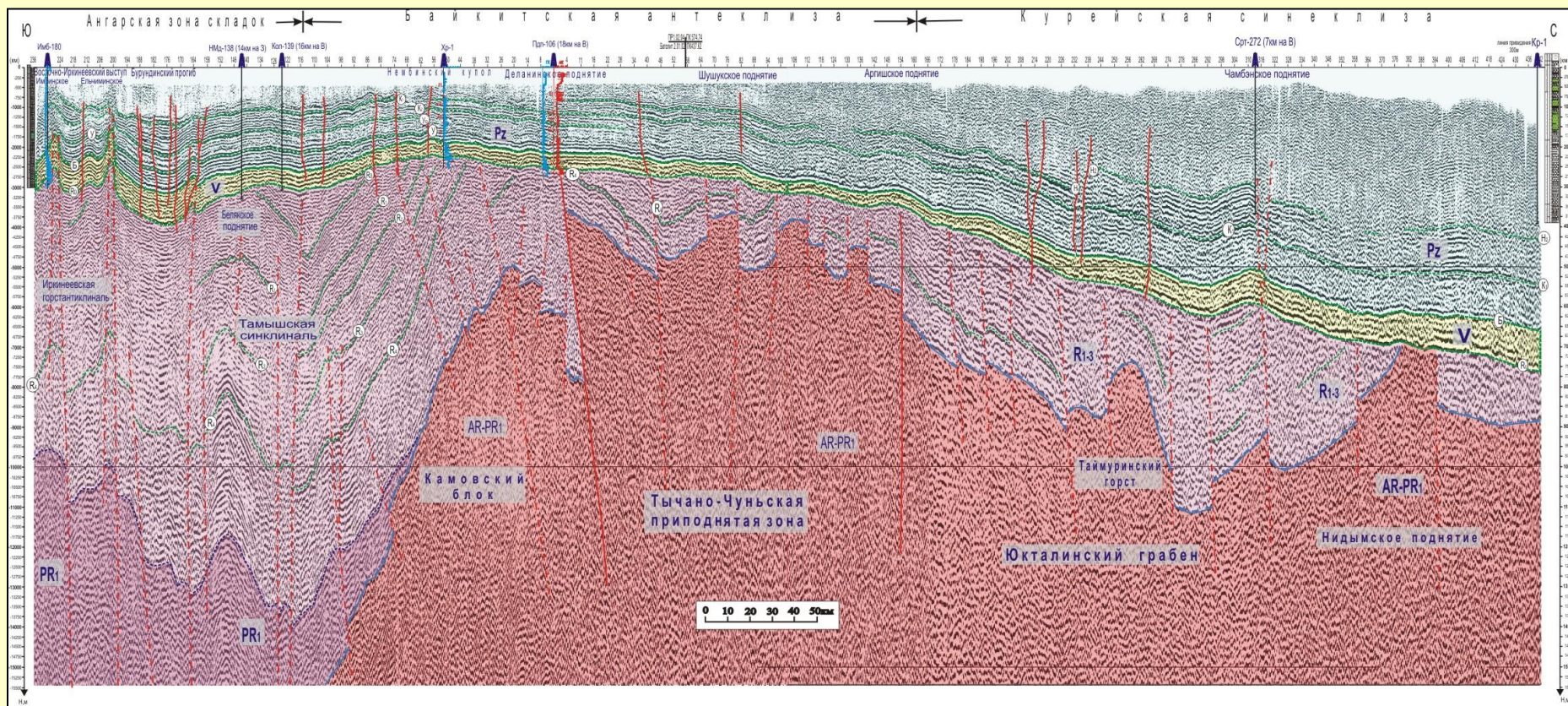
Северо-Западная часть



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Рифей

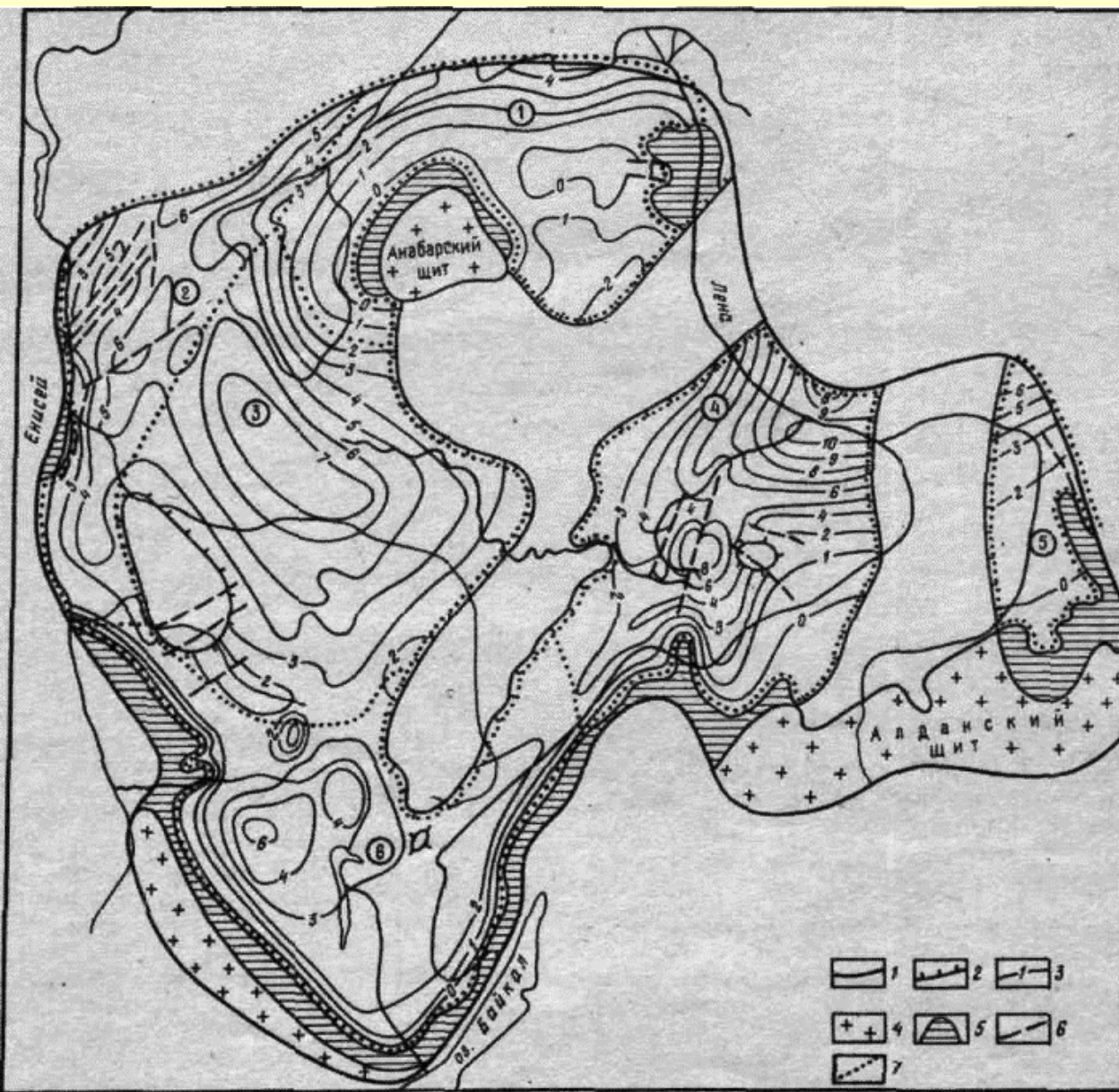
- Рифейские комплексы Сибирской платформы имеют площадное распространение



Глубинный сейсмогеологический разрез верхней части земной коры по опорному профилю “Алтай - Северная Земля”, Н=15,5 км (по А.А. Евграфову, 2003).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Схема расположения рифейских осадочных бассейнов



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

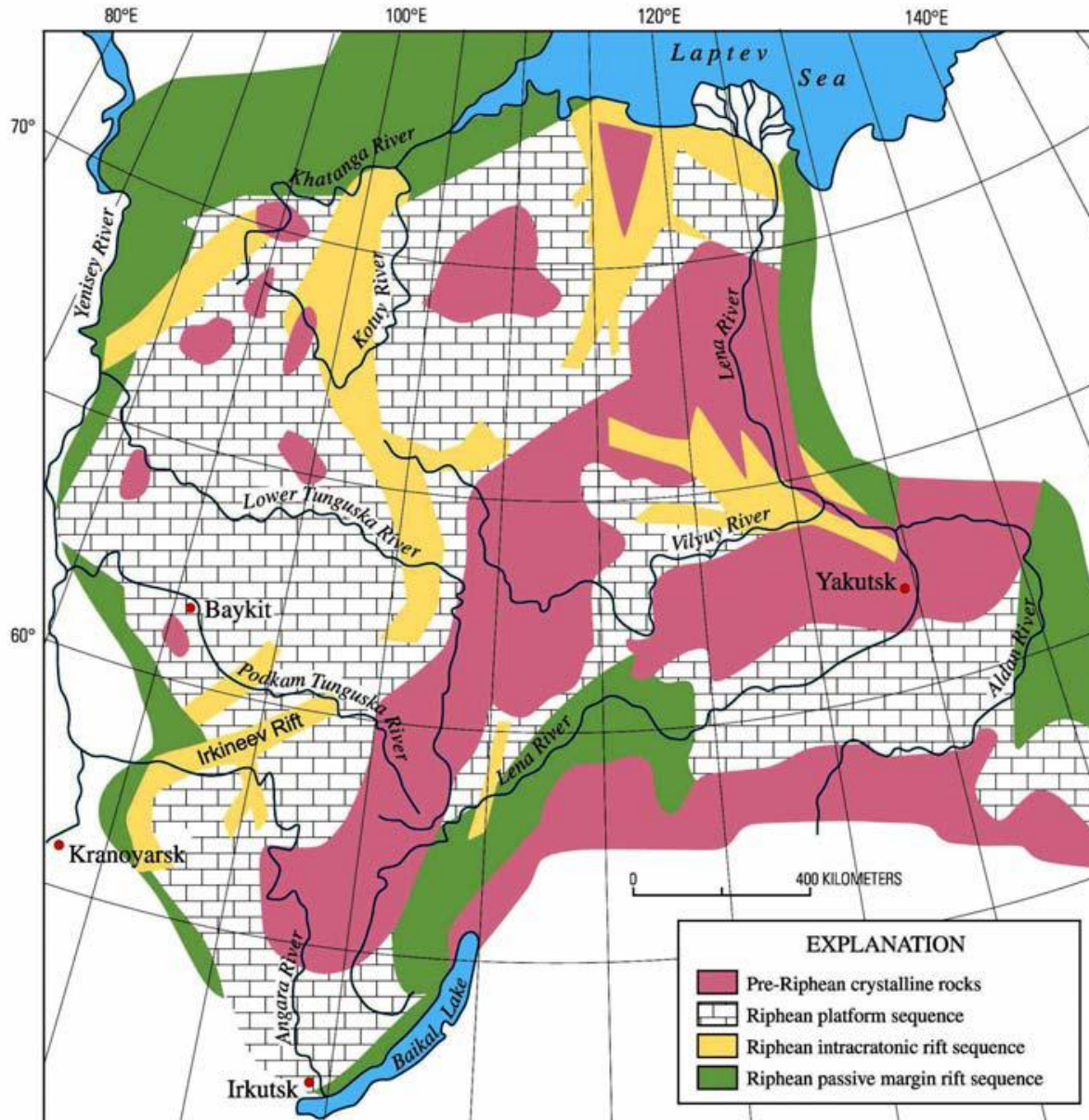


Figure 2. Distribution of Riphean rocks of Siberian craton beneath pre-Vendian unconformity. Modified from Kuznetsov (1997).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Три месторождения:

Юрубчено-Тохомское -
газоконденсатное,

Оморинское – газовое,

Куюмбинское -
нефтегазоконденсатное.

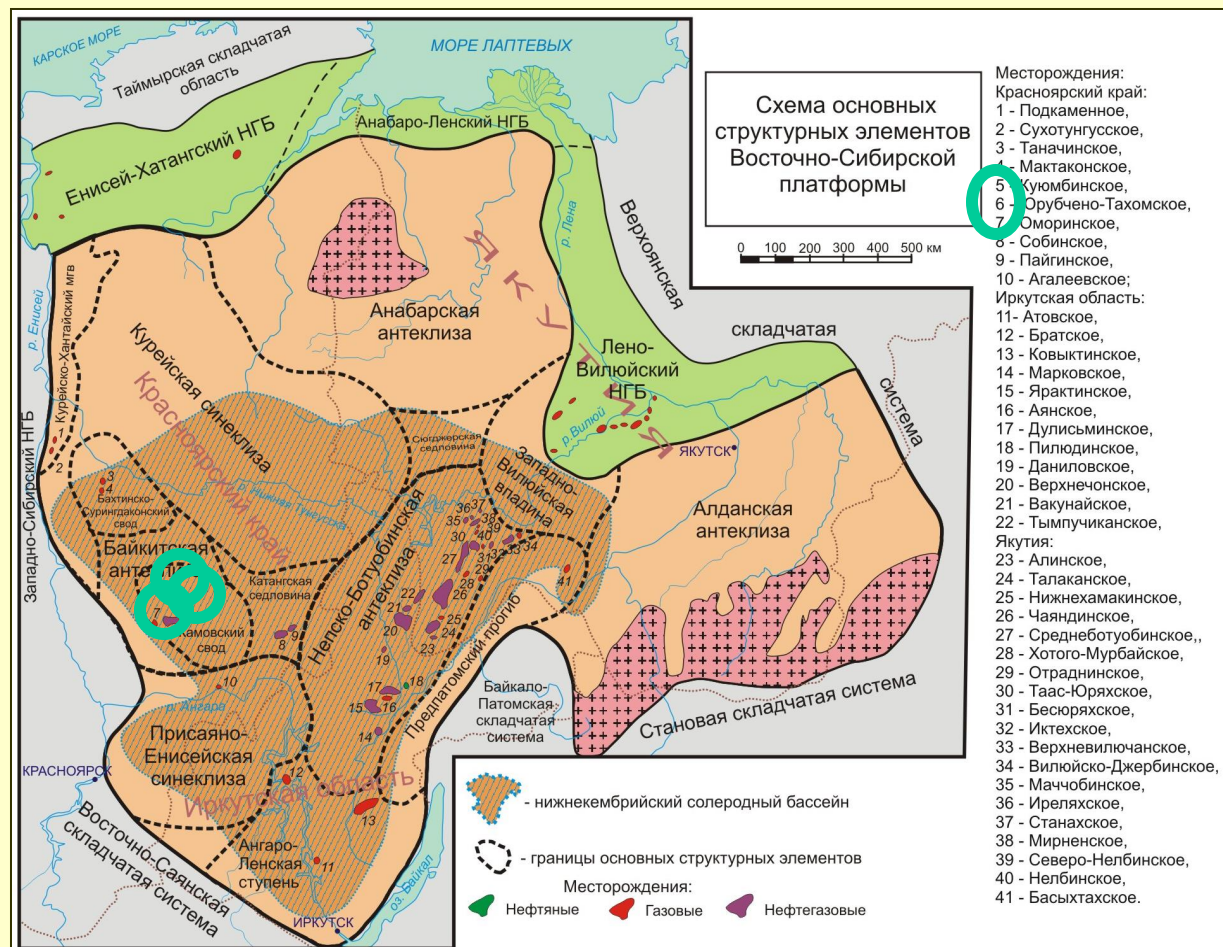
Карбонатные коллектора рифея
и терригенные коллектора
венда.

Региональный флюидоупор -
соленосные отложения
Усольской свиты нижнего
кембрия.

Характеристика: Залежи как правило массивные, литологически и тектонически экранированные, водоплавающие.

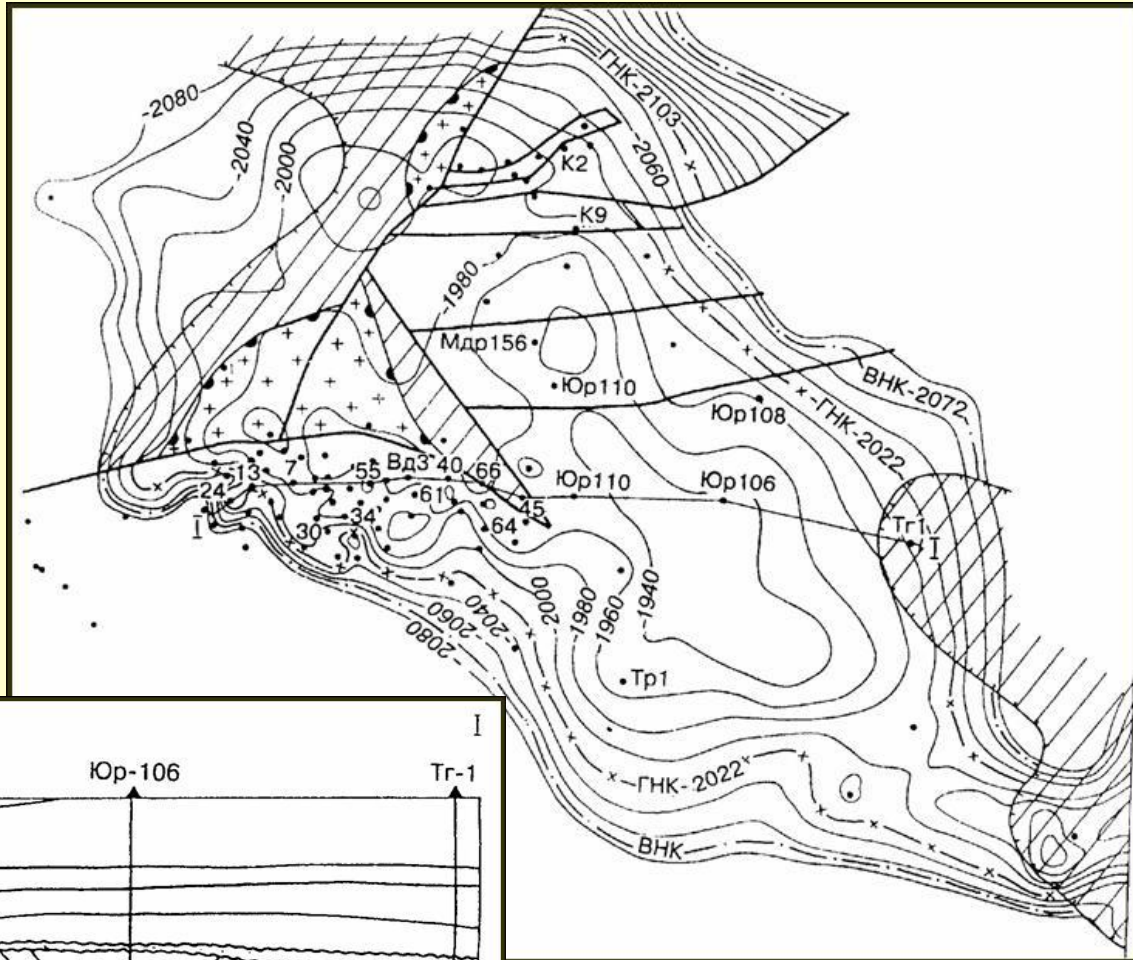
Характер пустотного пространства – трещинный и каверново-трещинный, реже поровый.

Нефти легкие, метановые, малопарафинистые, малосмолистые, бессернистые.

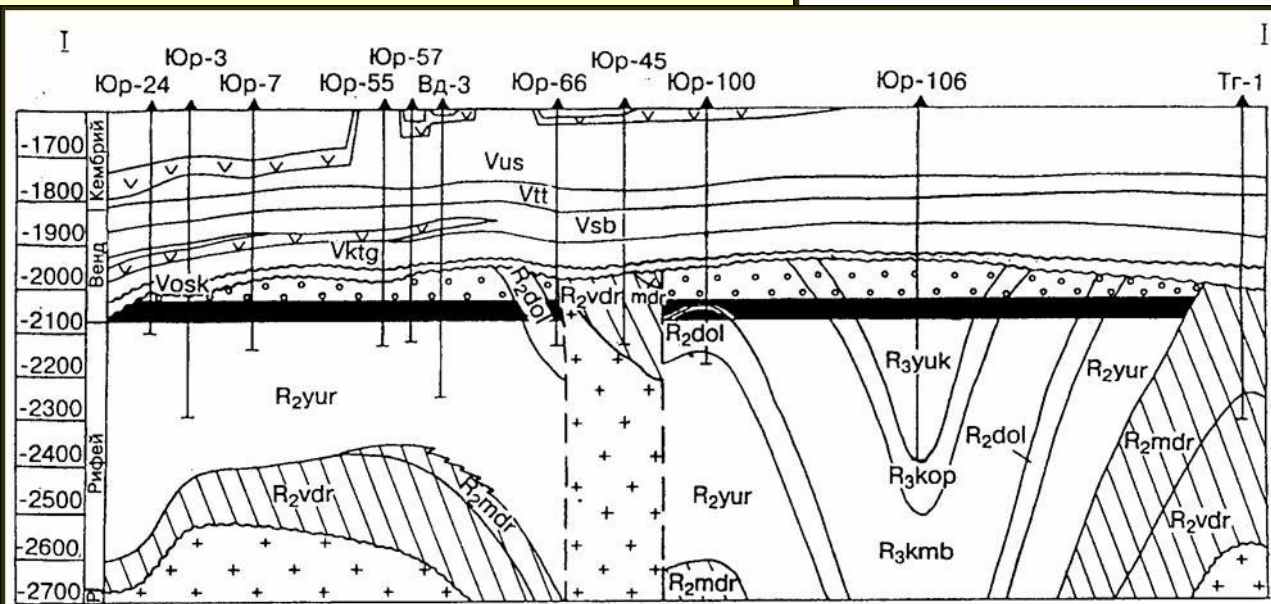


**Модель геологического строения Юрубчено-Тохомской зоны
(по А.Э. Конторовичу, А.Н. Изосимовой, А.А. Конторовичу и др., 1996)**

Выклинивание разновозрастных, литологически и фациально однородных рифейских толщ под предвендскую эрозионную поверхность. Притоки углеводородов получены из семи разновозрастных толщ рифея. Границами залежей служат выступы фундамента, выходы на эрозионную поверхность преимущественно глинистых толщ рифея и отдельные разломы. Строение рифейского комплекса складчато-блоковое.



**Структурная карта
эрозионной поверхности
рифейских отложений**



**Схематический профиль
Юрубчено-Тохомской зоны**

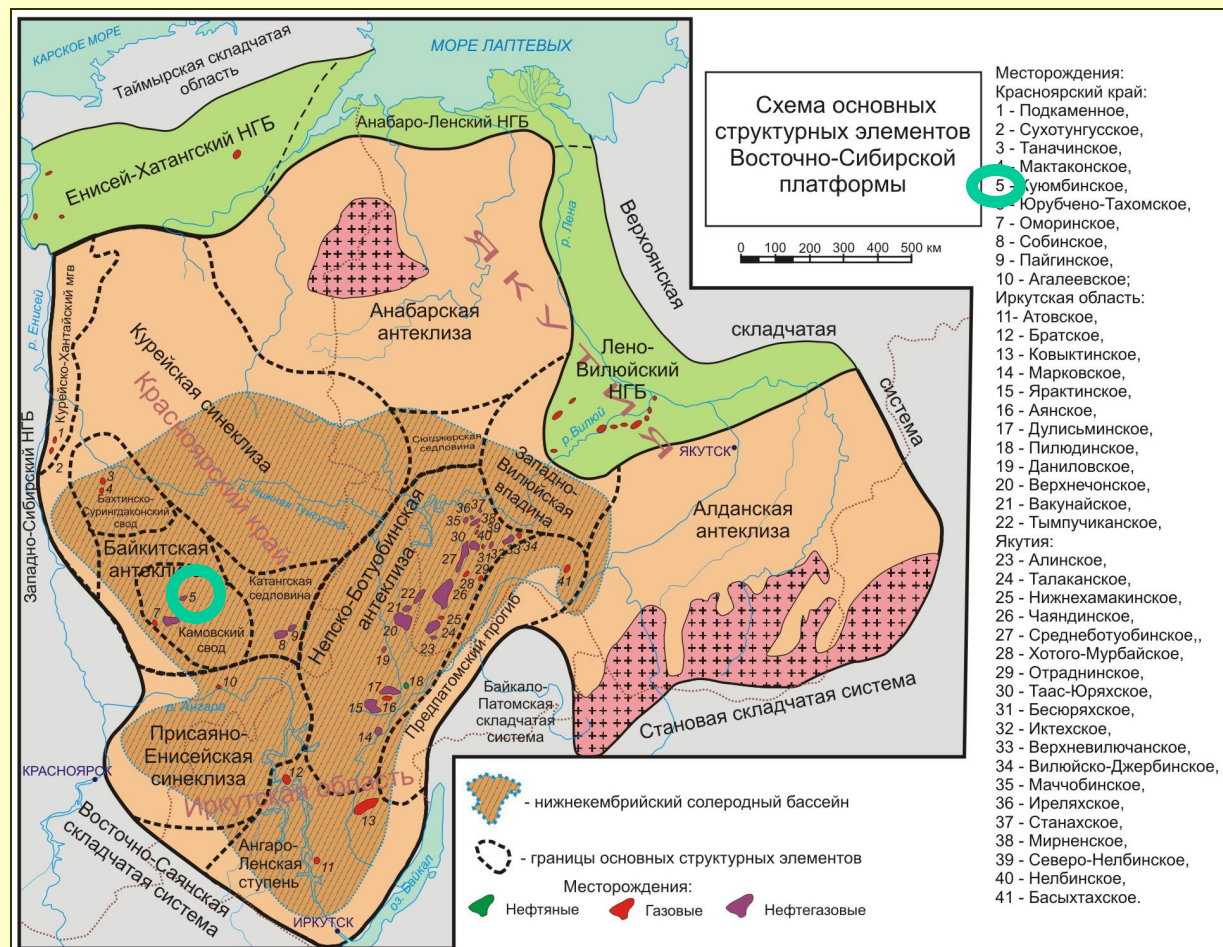
Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Куюмбинское месторождение:
позиция:

1) Эвенкийский автономный округ Красноярского края

2) центральная часть Камовского свода Байкитской антеклизы Сибирской платформы

3) Байкитская нефтегазоносная область Тунгусского нефтегазоносного бассейна



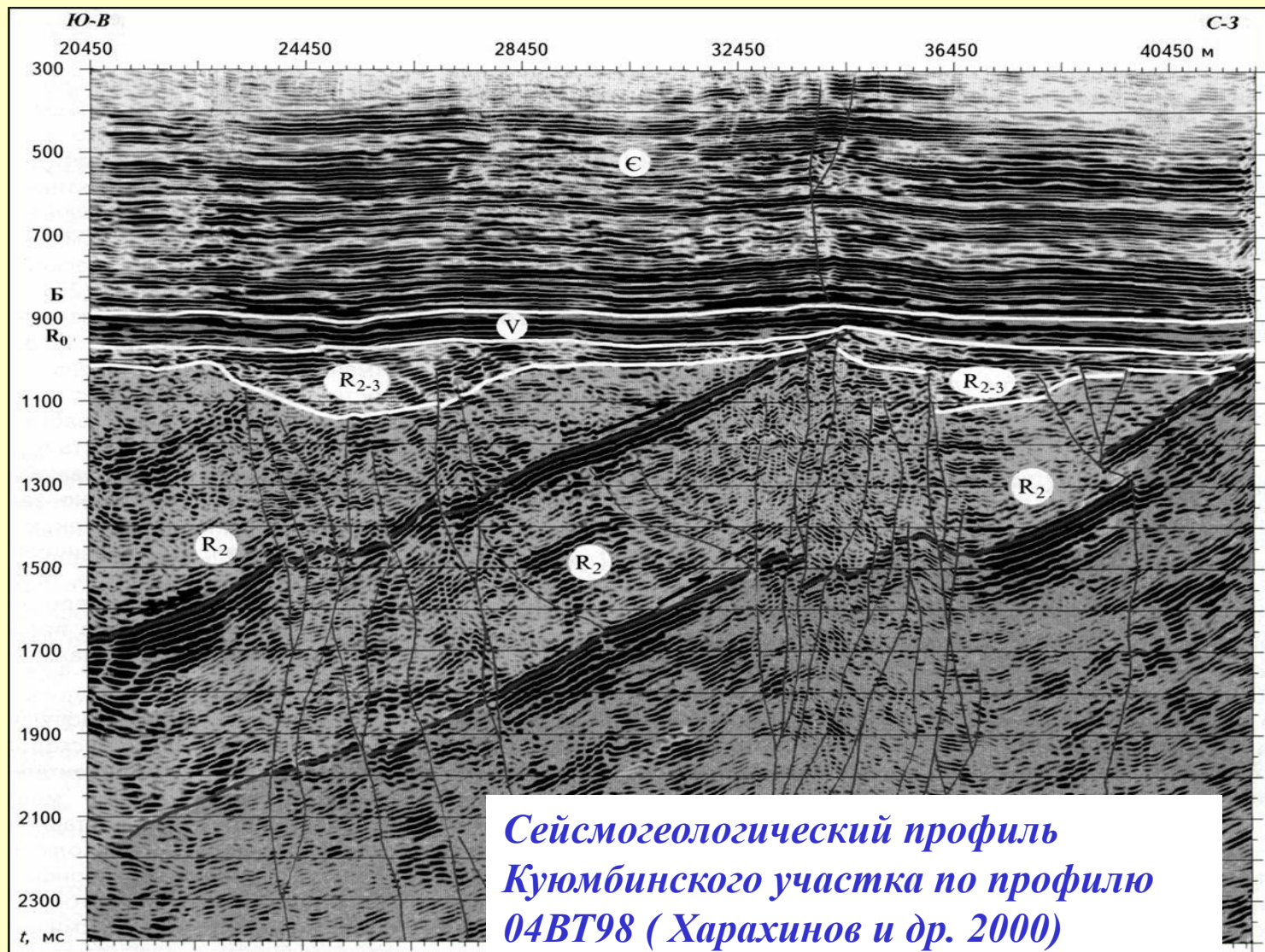
Характеристика: месторождение нефтегазоконденсатное, залежь массивная, литологически и тектонически экранированная, коллекторы карбонатные, с трещинным и каверновым типом пустотного пространства. Нефти метановые, малопарафинистые, малосмолистые, бессернистые, легкие. Открыто в 1973 году параметрической скважиной К-1, давшей промышленный приток УВ из отложений рифея

Рисунок С.В.Фролова (МГУ).

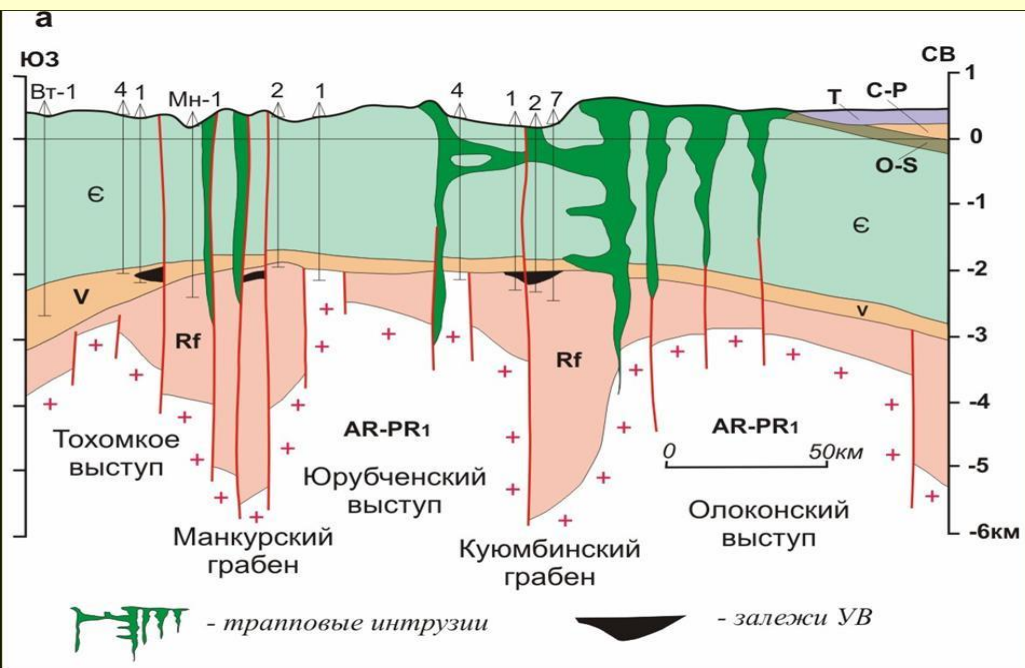
Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Двучленное строение рифейских толщ по данным сейсморазведки. Верхняя часть разреза (150-450 м), средний-верхний рифей, лежит субгоризонтально и резко латерально неоднородна.

Нижняя часть (нижний-средний рифей) залегает наклонно, интенсивно дислоцирована, разбита на ступени. Разломная тектоника контролирует развитие трещиноватости и литолого-фациальную неоднородность



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



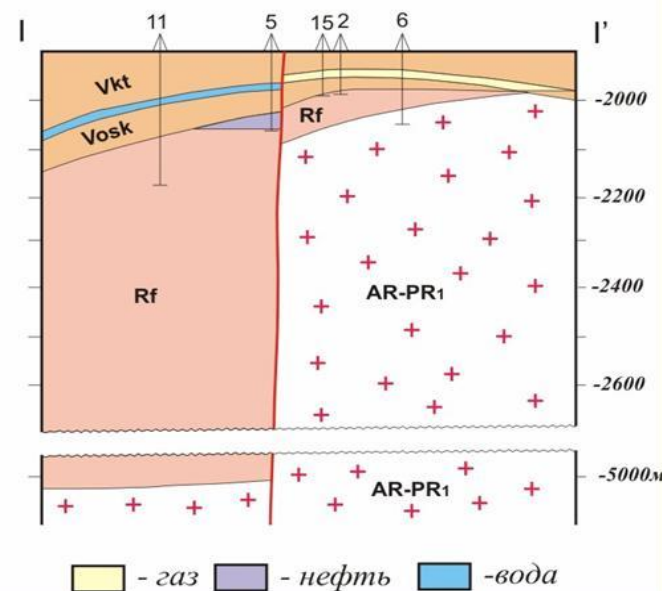
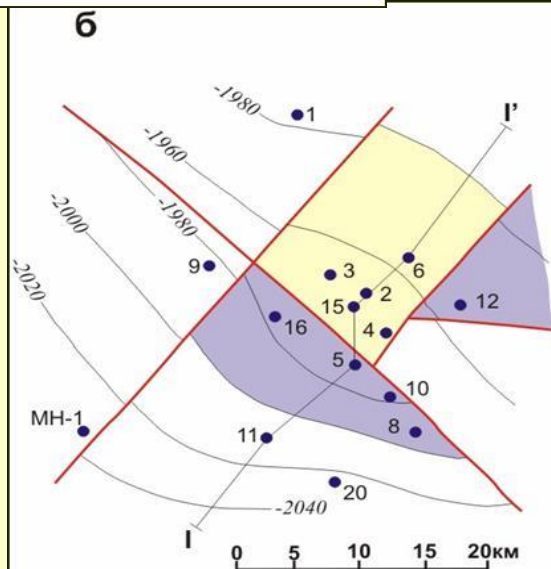
Модель Соколова Б.А, Егорова В.А

Нефтегазовая залежь, приуроченная к докембрийским отложениям

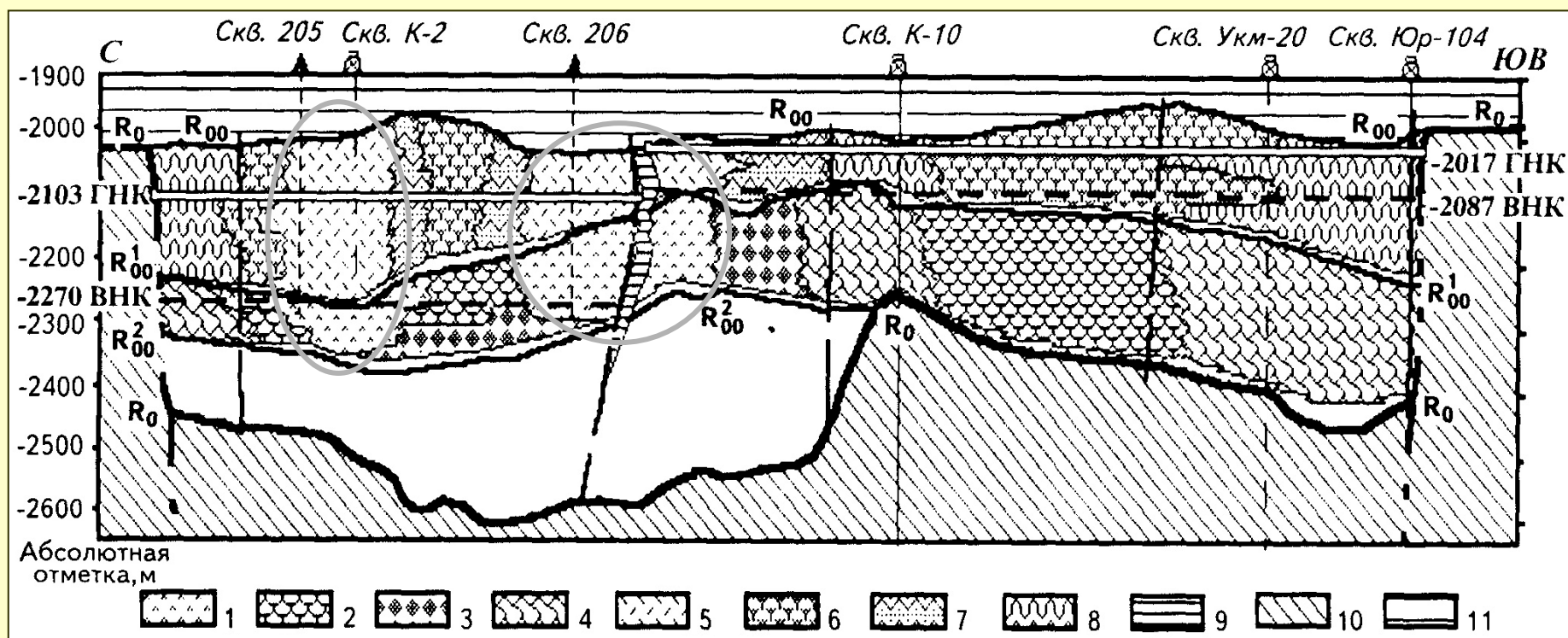
Залежь разбита серией субвертикальных разрывных нарушений на блоки

На поверхность предвендского размыва выведены разновозрастные образования, начиная от нижнепротерозойских до верхнерифейских.

Залежи нефти и газа встречаются только в тех структурах, которые в предвендское время не испытали существенного воздымания.



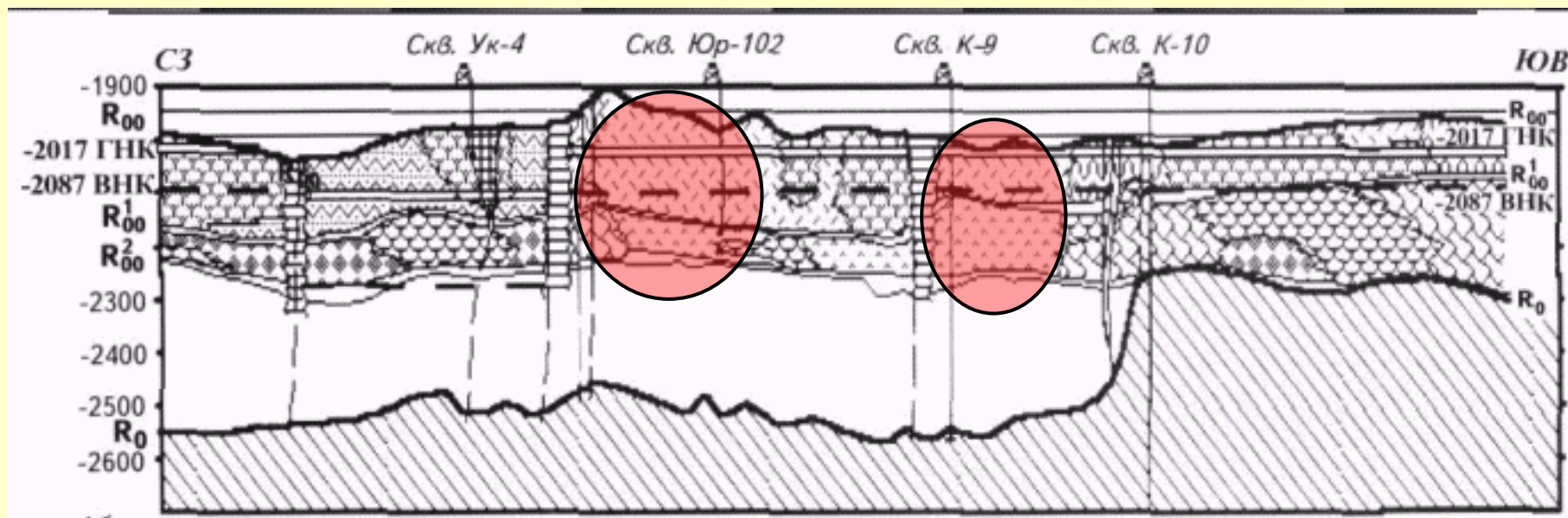
По комплексу геолого-геофизических данных по латерали выделяется до 7 типов разреза, емкостно-фильтрационные свойства в которых ухудшаются от чистых доломитов к песчано-глинистым разностям. Расположение зон по площади является мозаичным или полосовидным. Приразломные зоны, хотя и являются участками интенсивной трещиноватости и брекчирования, не являются коллекторскими – пустоты разного генезиса здесь заполнены минеральным веществом из-за интенсивной гидротермальной деятельности.



Сейсмогеологический разрез вкрест простирания Куюмбинского грабена (север-юг) (по Славкину и др. 1999). Рифейская терригенно-карбонатная формация (R_2) – интервал R_{00}^2 - R_{00}^1 : тип разреза: 1 - 1-2-й, 2 – 3-й, 3 – 4-й, 4 – 6-й; интервал R_{00}^2 - R_{00}^1 : тип разреза: 5 – 1-2-й, 6 – 3-й, 7 – 4-й, 8 – 6-й, 9 – 5-й; 10 – рифейская карбонатная формация (R_2), 11 - венд

Модель геологического строения Куюмбинского месторождения (Славкин В.С. и др., 1999).

Сейсмогеологический разрез по простиранию Куюмбинского грабена, с выделением типов разреза (В.С. Славкин, В.Е. Зиньковский, Н.Е. Соколова, Е.А. Давыдова, Геология нефти и газа, 1999, 11-12)



Конседиментационно развивавшаяся структурная форма – Куюмбинский грабен

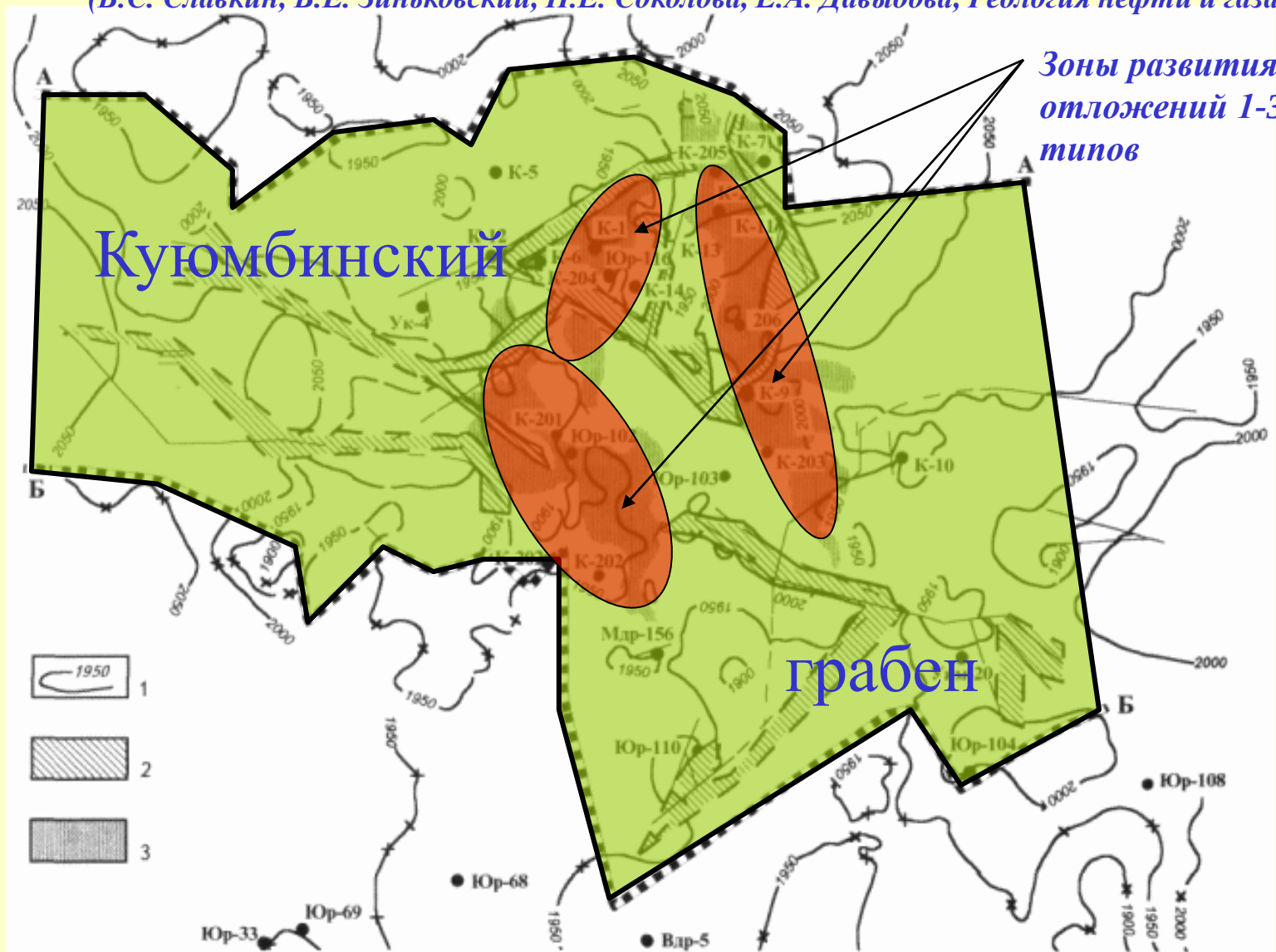
Субгоризонтальное пластовое залегание рифейских комплексов (юрубченского) и (куюмбинского);

**Конседиментационность развития ряда структурно-морфологических элементов палеорельефа
возможность существования резких фациальных замещений**

Модель геологического строения Куюмбинского месторождения (Славкин В.С. и др., 1999)

Структурная карта подошвы вендских отложений, с нанесением распространения типов разрезов

(В.С. Славкин, В.Е. Зиньковский, Н.Е. Соколова, Е.А. Давыдова, Геология нефти и газа, 1999, 11-12)



карта распространения отложений 1-3 типов, которые объединяются в 6 зон, общей площадью порядка 350 кв. км.

Модель гидрогеологического
строения Куюмбинского
месторождения

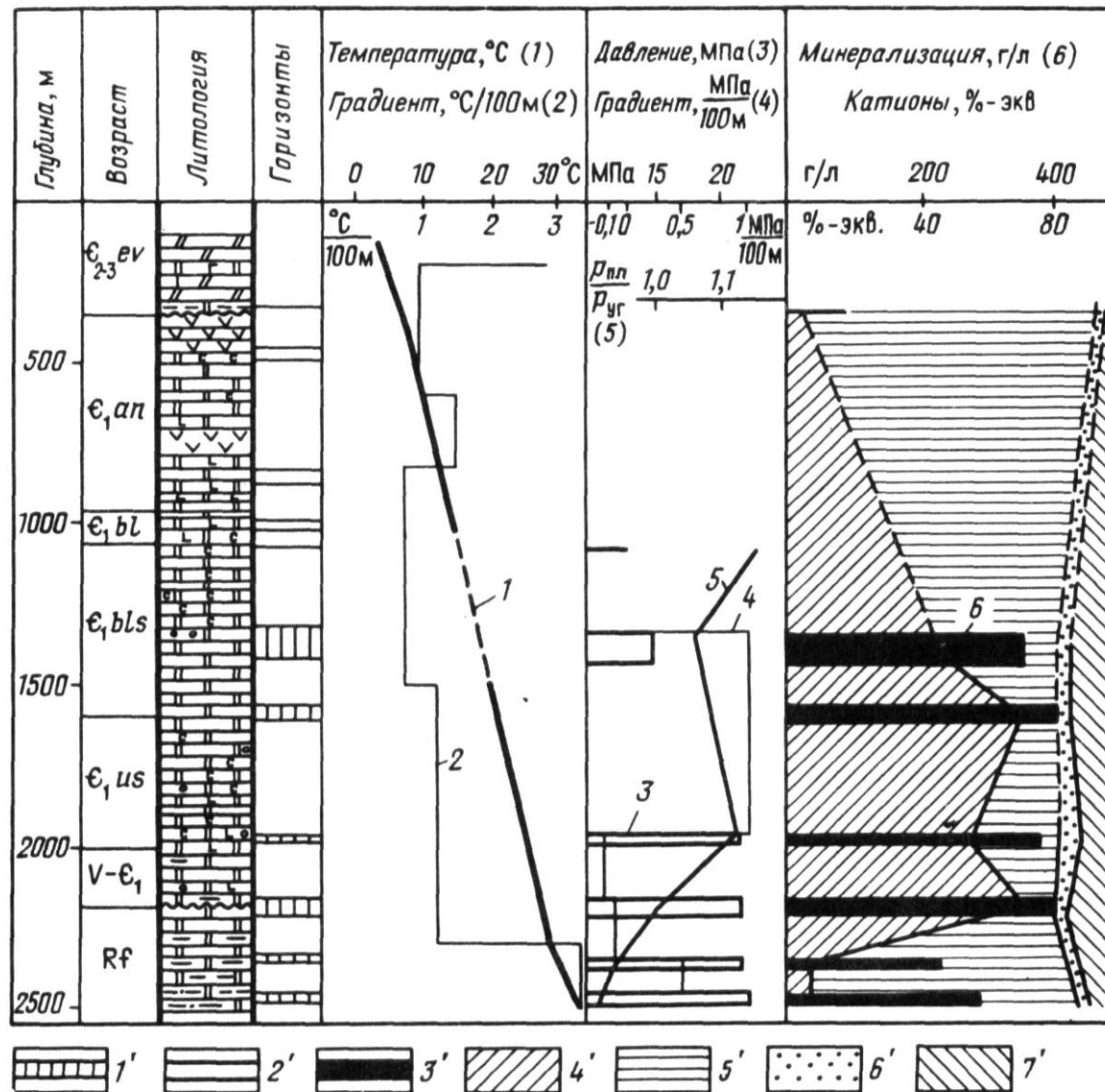


Рис.4.2.2. Гидрогеологический разрез Куюмбинского месторождения.

Горизонты, выделенные по результатам: 1' – испытаний, 2' – бурения (по поглощениям и проявлениям); 3' – термометрии; содержание, %-экв: 4' – кальция, 5' – натрия, 6' – калия, 7' – магния. Свиты: $\text{Є}_{2-3\text{ev}}$ – эвенкитская, $\text{Є}_{1\text{an}}$ – ангарская, $\text{Є}_{1\text{bl}}$ – булайская, $\text{Є}_{1\text{bls}}$ – бельская, $\text{Є}_{1\text{us}}$ – усольская.

(Гидрогеологические условия..., 1987 г.)

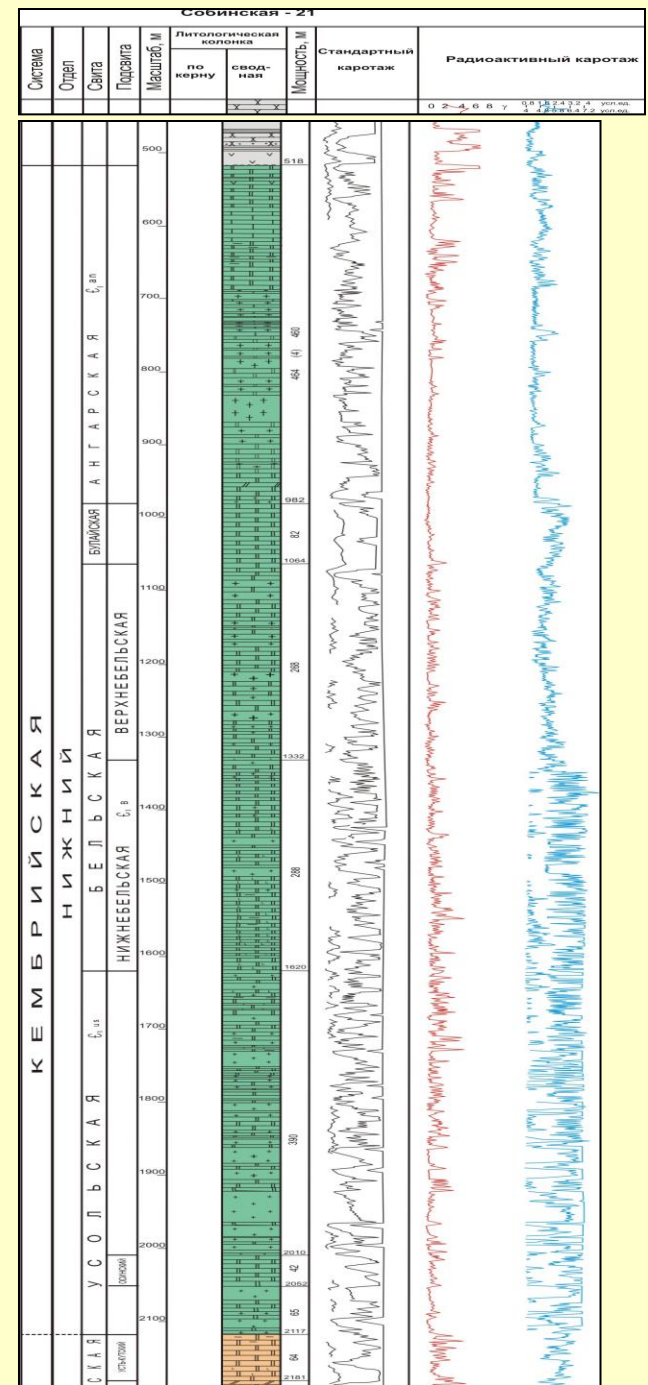
Венд

- | Протерозойская - PR | | П а л е о з о и с к а я - PZ | | | | | Группа |
|--------------------------|--------------|------------------------------|--|----------------------------------|---|------------------------------------|------------------------------|
| Рифейская - R | Вендская - V | К е м б р и й с к а я - C | | | | | Система |
| Верхний - R ₃ | | Н и ж н и й - C ₁ | | | | | Отдел |
| | | Томтоцкий C _{1t} | А т д а б а н с к и й - C _{1at} | Ботомский - C _{1b} | Тойонокий - C _{1тп} - Амгинский - C _{2am} | Средний-верхний - C _{2,3} | Ярус |
| | | Татарская V-C _{1т} | У с о л ь с к а я - C _{1us} | Бел ь с к а я - C _{1ba} | Булайская C _{1bul} | Звенкийская - C _{2,3ев} | Свита |
| | | Собинская Vsb | | | | | |
| | | Катангская Vkt | | | | | |
| | | Оскобинская Vosk | | | | | |
| | | Ванаарская Vvn | Осинский | | | | Региональный горизонт |
| | Р1-0 | | | | | | Пласт, продуктивный горизонт |
| | | | | | | | Литологическая колонка |
| 100 | 200 | 20 | 70 | 60 | 50 | 500 | Средняя мощность, м |

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Кембрий

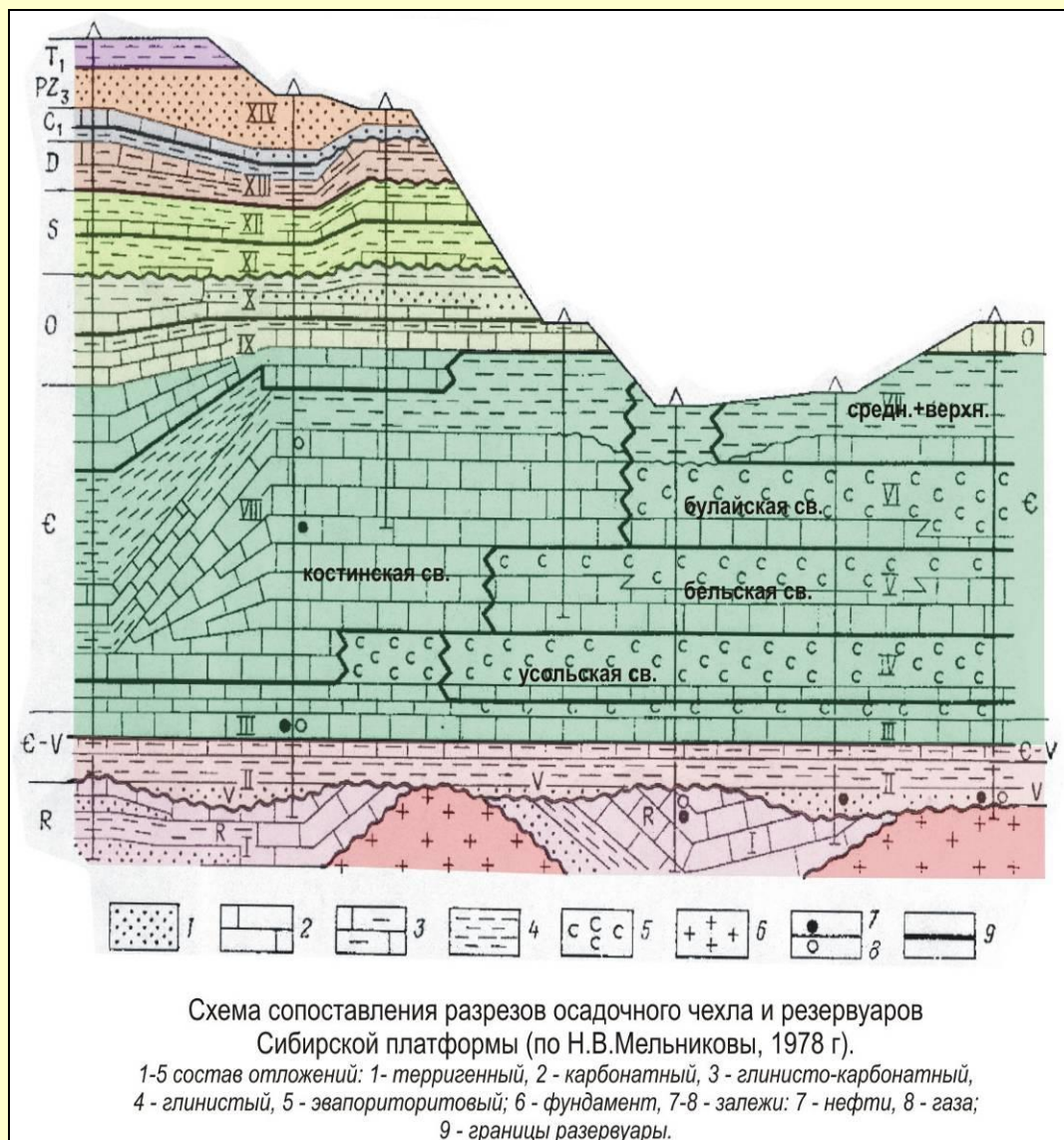
- Кембрийские отложения составляют наиболее мощный (1-2 км на антекклизах и до 2,5-3,5 в синекклизах) комплекс осадочного чехла большинства районов Восточной Сибири.
- На вендских отложениях они залегают согласно.
- В центральных частях платформы он преимущественно сложен переслаивающимися пачками солей, доломитов и глинистых известняков (усольская, бельская, булайская, ангарская и литвинцевская свиты). В верхней части (эвенкийская свита) галогенные породы отсутствуют.
- В разрезах западной части платформы разрез преимущественно карбонатный (костинская свита).
- В восточных и северных районах в раннем-среднем кембрии местами накапливались маломощные (до 100 м) толщи битуминозных глинисто-кремнистых известняков (куонамская свита).

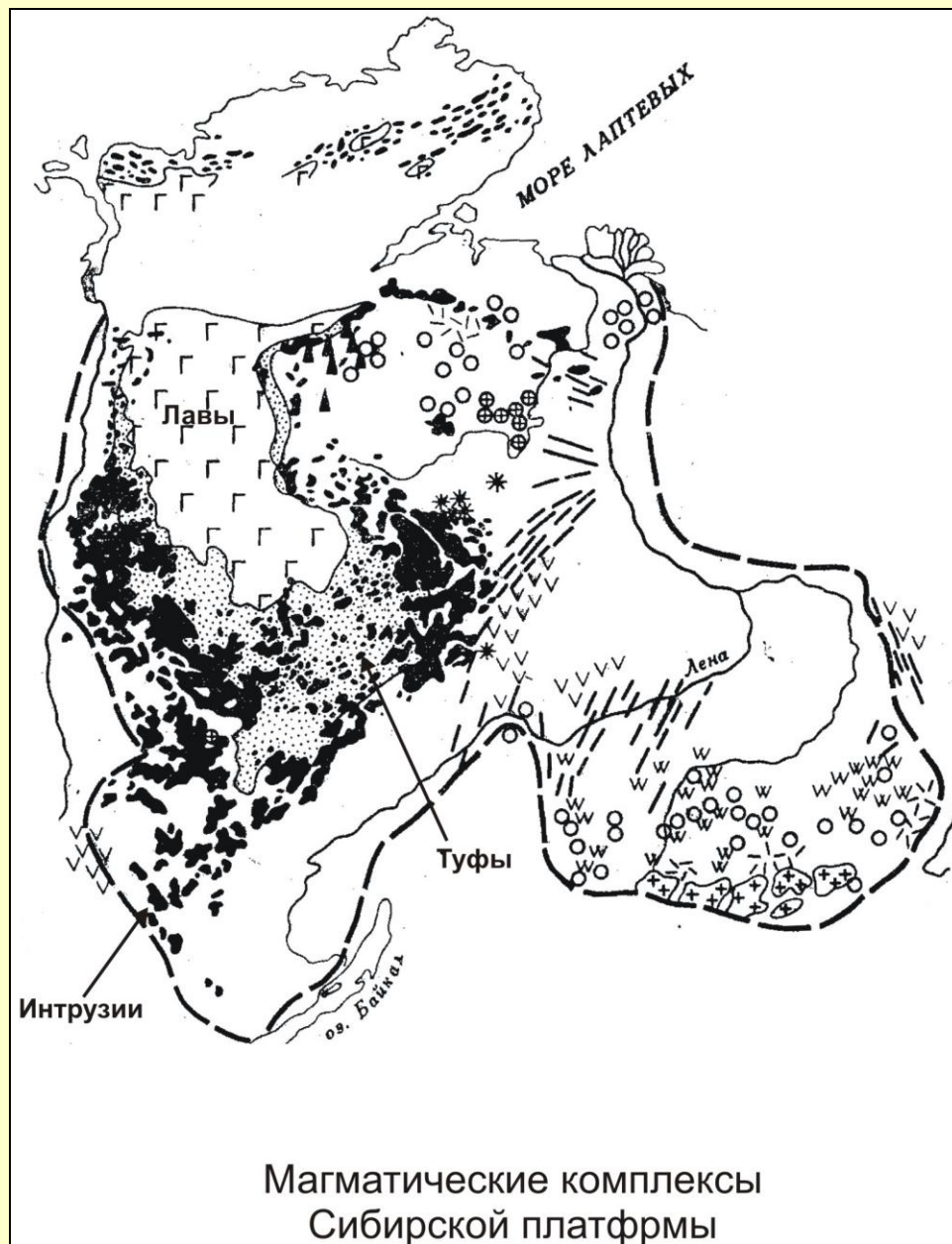


Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Ордовик-пермь

- Эти отложения характерны для погруженных частей платформы.
- Ордовик (до 800 м в Туринской впадине) сложен как терригенными (преобладают на юге), так и карбонатными образованиями.
- Силур представлен в основном карбонатами, реже с прослоями терригенных (обычно в основании) пород, мощностью от первых сотен м до 1 км (Игаро-Норильский район).
- Девонско-нижекаменноугольные отложения в основном представлены красно- и пестроцветными породами. На севере платформы появляются карбонаты, местами (также и на востоке, напр., в Кемпедяйской впадине) и сульфатно-соленосные образования, иногда с вулканогенными образованиями. Мощность комплекса может достигать 1,2 (Норильский район) – 3,0 км (Кемпедяйская впадина).
- Среднекаменноугольно-пермские отложения являются субконтинентальными терригенными и угленосными. Мощность до 1,0-1,5 км (северо-запад Тунгусской синеклизы).





Верхнепермско-триасовые комплексы

- На рубеже перми и триаса на большей части территории Сибирской платформы резко усилилась вулканическая деятельность.
- Этот процесс привел к образованию трапповой формации, проявившейся как в виде интрузий, так и поверхностных излияний основной по составу магмы.
- Триас в основном представлен вулканогенно-осадочными образованиями: базальтами, туфогенными и туфогенно-осадочными породами.
- Мощность триасовых образований (индский и оленекский века раннего триаса) на севере Тунгусской синеклизы достигает 3,5 км, в ее центре – 0,6-1,5 км.

Камовский свод

Куюмбинская площадь

Eng-154 Птк-1 112 9 16 18 13 10 Вдр-4 303 Вдр-2 89 Вдр-6 114 Tr-1

E_{2-3}^{ev}
 E_{1-2}^{ang}
 E_{blis}
 E_{us}
 V

R_{ydr} R_f R_{kmb} R_{dls} R_{jrb} R_{mdr} R_{ydr}

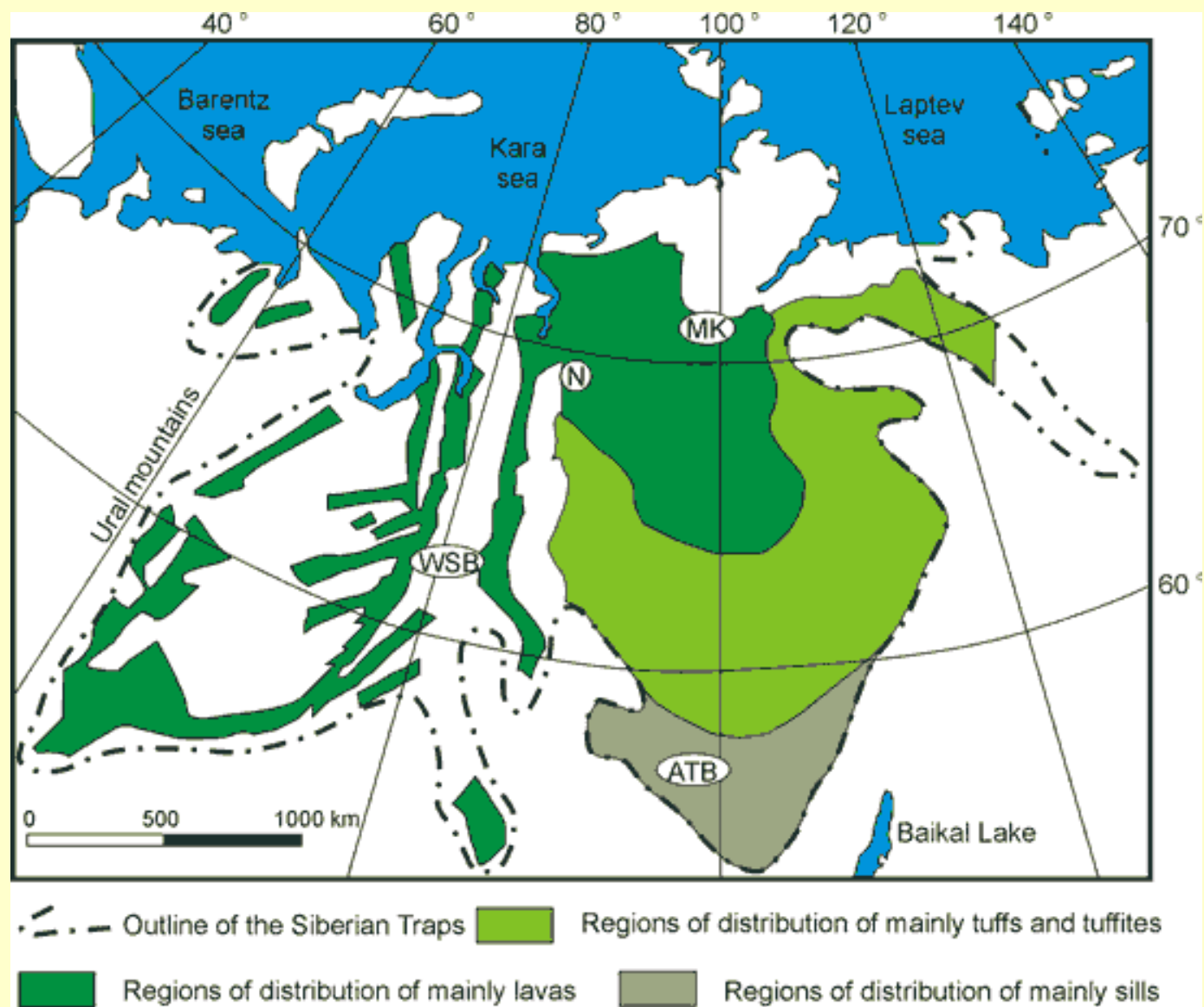
0 20 40km

AR-PR₁

Интрузии долеритов на
Камовском своде *(по А.В.Хоменко,
2002)*

-
- Суммарная мощность силлов в осадочном чехле западной части Сибирской платформы
(по А.Э.Конторовичу, А.В.Хоменко, 2001)

Интрузивные комплексы



Siberian Traps (modified from Masaitis, 1983). WSB – West Siberian Basin, ATB – Angara-Taseevskaya syncline, N – Noril'sk, MK – Maymecha-Kotuy.

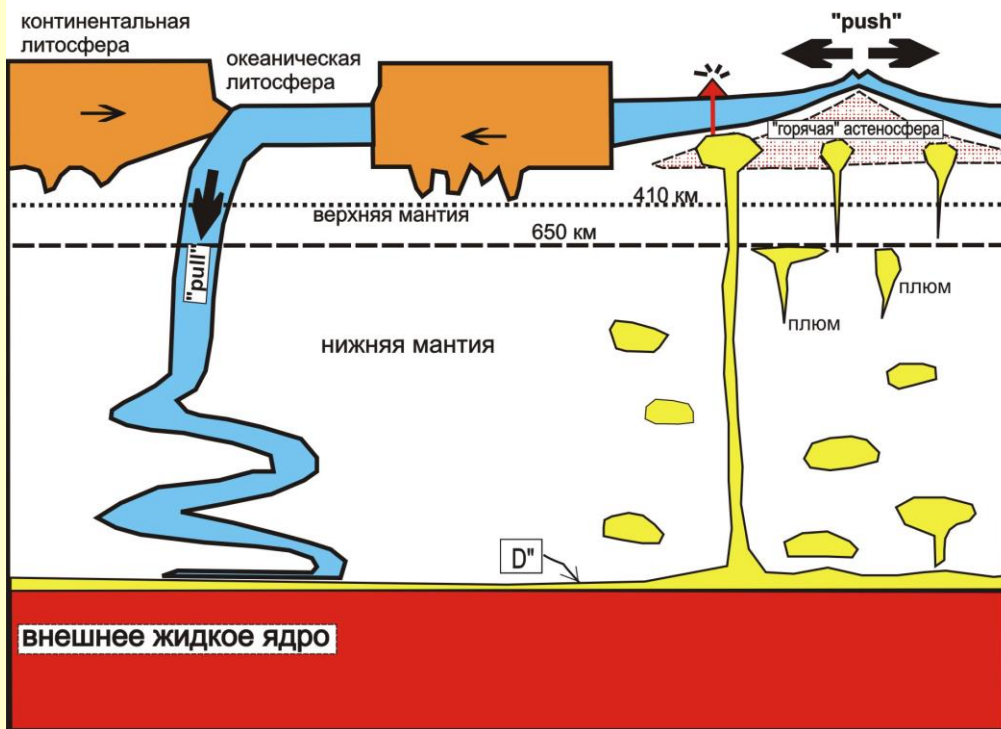
Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



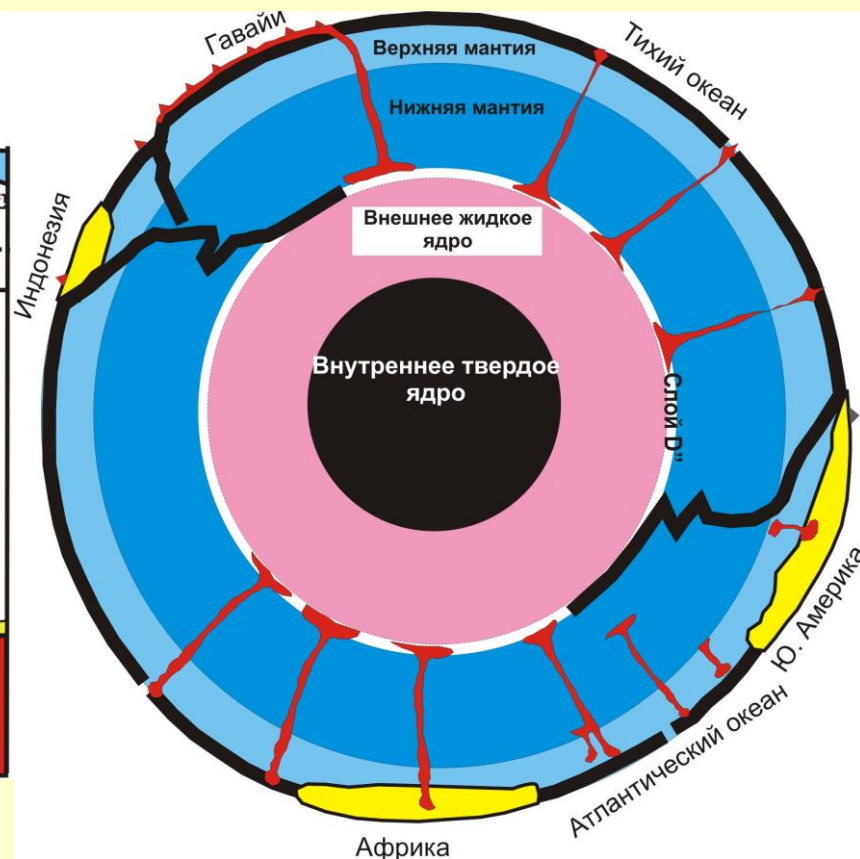
Восточная Сибирь в конце пермского периода (“Вокруг Света”, №1 (2820), 2009)

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Внемасштабная модель геодинамики Земли



Внемасштабная геодинамическая модель современной Земли. Желтым показаны плюмы



Геодинамическая модель современной Земли. Красным показаны плюмы.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



Лавы заливают до 2/3 площади Восточной Сибири, формируя многослойные базальтовые плато, которые выражены в виде Среднесибирского плоскогорья в районе рек Нижняя и Подкаменная Тунгусска, Курейка, Котуй, Анабар и Вилюй.

Движущийся поток базальтовой лавы на Гавайских островах («пайхое-хое»).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



Базальты плато Путорана (Восточная Сибирь), излившиеся почти мгновенно – всего за тысячу лет, достигают толщины 1,8 км (“Вокруг Света”, №1 (2820), 2009)

Справка: базальты трапповой формации Восточной Сибири в Тунгусской синеклизе образовались возможно в течение не более 8000 лет. Они покрыли до 7 миллионов квадратных километров суши. Из недр было выброшено 2-3 млн км³ вулканических материалов, включая миллионы гигатонн двуокиси углерода. Это привело к увеличению ее концентрации в атмосфере в 7—10 раз. Для сравнения: если человечество в течение 100 лет сожжет все имеющиеся запасы ископаемого топлива, то это повысит содержание углекислого газа в атмосфере в 2—3 раза (“Вокруг Света”, №1 (2820), 2009).

Вмещающими для базальтов породами являются толщи угленосной тунгусской серии.

По составу это песчаники различной степени зернистости, аргиллиты, алевролиты, гравелиты, редкие маломощные прослои конгломератов и пласты каменных углей до антрацитов. Мощность отложений тунгусской серии сильно варьирует: от 20-40 метров на сводах валов до 600 метров в осевых частях прогибов.

Помимо угля, одним из важнейших и стратегических полезных ископаемых этого региона является никель, одно из месторождений которого локализовано рядом с Норильском.

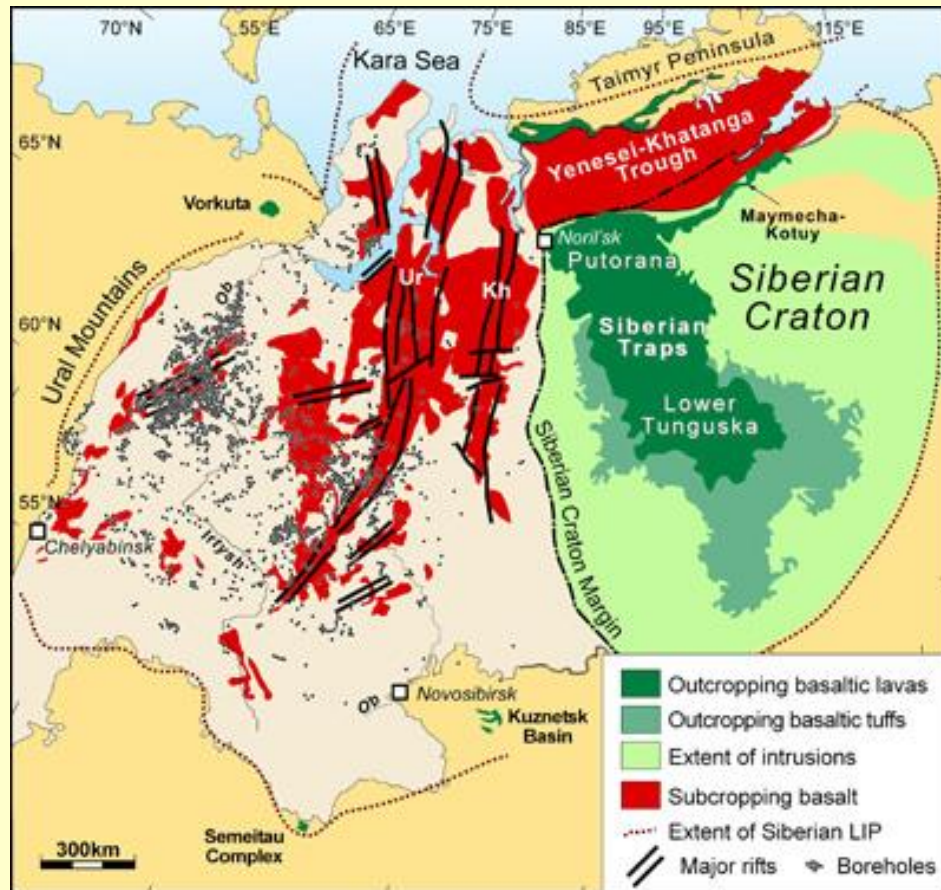
Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Перенесемся в пермский период (299–251 млн лет назад). К его концу вымерло более 200 (60–80% появившихся в начале палеозойской эры) семейств живых организмов и до 80–90% видов животных и растений. В итоге 9 видов из 10 погибли. Самые драматичные события произошли в морях и океанах, где от 250 тысяч осталось только около 10 тысяч видов. В воде вымерло 95%, а на суше – 70% видов организмов. Вымирание динозавров и других существ в конце мезозоя было в три раза слабее.

Во второй половине пермского периода 2/3 площади суперконтинента Пангеи, объединявшего тогда все материки, оказываются под властью засухи. В Восточной Сибири из гигантских глубоких трещин на поверхность земли выливаются миллионы кубических километров базальтовой лавы, которая течет по равнинам и низменностям, выжигая все вокруг. Лавы заливают до 2/3 площади Восточной Сибири, формируя многослойные базальтовые плато.



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



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Жар отсюда постепенно распространяется на все большие расстояния, высушивая реки и испаряя горизонты подземных вод. К концу периода выливается до 2 млн км³ лавы. Эти глубинные разломы появились в результате удара снизу гигантской капли магматического вещества, или плюма, которые и сегодня регулярно отрываются от внешнего ядра и за 5-10 млн лет достигают поверхности. Кроме механического разрушения верхних слоев земной коры, происходит их плавление снизу. По трещинам магма из недр земли выливается на поверхность.

Массовое вымирание (МВ) - это относительно кратковременное и в масштабе геологического времени синхронное ступенчатое вымирание в ходе биотического кризиса большого числа таксонов организмов, принадлежащих различным систематическим и экологическим группам, что приводит к временному глобальному снижению таксономического разнообразия биосферы (А.С.Алексеев, МГУ)

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

СЦЕНАРИЙ МВ:

1.ВЫБРОС В АТМОСФЕРУ БОЛЬШОГО КОЛИЧЕСТВА УГЛЕКИСЛОГО ГАЗА И ПАРОВ ВОДЫ – ПАРНИКОВЫХ ГАЗОВ, ВЫЗЫВАЮЩИХ ГЛОБАЛЬНОЕ ПОТЕПЛЕНИЕ

2.СОКРАЩЕНИЕ ПЛОЩАДИ ЛЕСОВ ИЗ-ЗА ПОЖАРОВ И ЗАСУХИ, СДВИГ БАЛАНСА КИСЛОРОД-УГЛЕКИСЛЫЙ ГАЗ В ПОЛЬЗУ ПОСЛЕДНЕГО

3.РАЗОГРЕВ ПОВЕРХНОСТИ ЗЕМЛИ, СОКРАЩЕНИЕ НА СУШЕ ИСТОЧНИКОВ ВОДЫ ИЗ-ЗА ЕЕ АКТИВНОГО ИСПАРЕНИЯ, ПОЯВЛЕНИЕ СУХИХ ГРОЗ (ДОЖДЬ ИСПАРЯЕТСЯ НАД ПОВЕРХНОСТЬЮ РАЗОГРЕТОЙ ЗЕМЛИ)

4.АКТИВНОЕ ИСПАРЕНИЕ ВОДЫ ПРИВОДИТ К ОСЛОЛЕНИЮ БАССЕЙНОВ И ИХ ИСЧЕЗНОВЕНИЮ НА СУШЕ. ЭФФЕКТ «ЗАСАЛИВАНИЯ ЗАЖИВО»

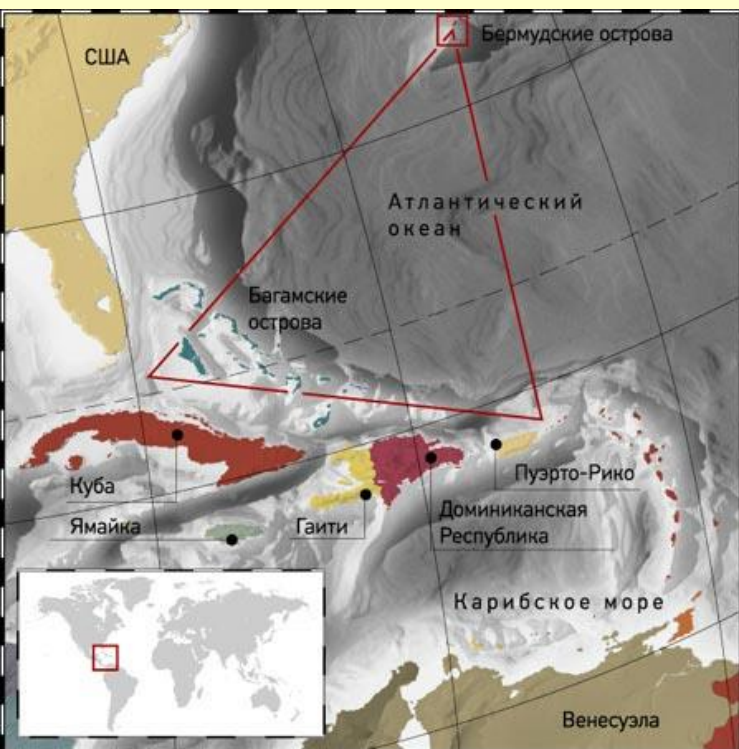
5.«ПЕРЕД ПЛЮМОМ» БЫЛО ОЛЕДЕНЕНИЕ, И ЛЬДЫ ТАЮТ, УРОВЕНЬ МИРОВОГО ОКЕАНА ПОДНИМАЕТСЯ (ДО 200 М!), МОРСКИЕ ОБИТАТЕЛИ МЕЛКОВОДЬЯ СНАЧАЛА ГИБНУТ ОТ ОПРЕСНЕНИЯ МОРСКОЙ ВОДЫ, А ПОТОМ - «ТОНУТ». ВЫМИРАНИЕ НАЧАЛОСЬ С КОРАЛЛОВ.

6.ИСПАРЕНИЕ НАЧИНАЕТ ПРОЕБЛАДАТЬ НАД ОСАДКАМИ ПО ВСЕЙ ГИДРОСФЕРЕ, УРОВЕНЬ МИРОВОГО ОКЕАНА ПАДАЕТ, А СОЛЕННОСТЬ РАСТЕТ. ЭФФЕКТ «ЗАСАЛИВАНИЯ ЗАЖИВО» В ОКЕАНАХ

7.ПОНИЖЕНИЕ УРОВНЯ МОРЯ НА 200 МЕТРОВ ПРИВОДИТ К РАЗМОРОЗКЕ ЗАПАСОВ СЖИЖЕННОГО МЕТАНА НА ДНЕ МОРЕЙ И ОКЕАНОВ (ИЛИ ГАЗОГИДРАТОВ) – ОДНОГО ИЗ САМЫХ СИЛЬНЫХ ПАРНИКОВЫХ ГАЗОВ. ГАЗОГИДРАТЫ ЗАЛЕГАЮТ НА ЗНАЧИТЕЛЬНОЙ ГЛУБИНЕ И ПОГРЕБЕНЫ ДОННЫМИ ОСАДКАМИ. ИХ РАЗМОРОЗКА ПРИВЕЛА К КАТАСТРОФИЧЕСКОМУ ВЫБРОСУ ЧЕТЫРЕХ ТРИЛЛИОНОВ ТОНН МЕТАНА В АТМОСФЕРУ В ВИДЕ ГИГАНТСКИХ ПУЗЫРЕЙ.

8.ЭТА ГАЗОВАЯ АТАКА СОКРАТИЛА ДОЛЮ КИСЛОРОДА В ВОЗДУХЕ ДО 16% (СЕЙЧАС ОНА РАВНА 21%), ЗНАЧИТ ВСЕМ ЖИТЕЛЯМ ЗЕМЛИ СТАЛО ТЯЖЕЛЕЕ ДЫШАТЬ. В ГОРАХ И НА ВОЗВЫШЕННОСТЯХ, ГДЕ ВОЗДУХ РАЗРЯЖЕН, КИСЛОРОДА МЕНЬШЕ ВСЕГО. ТЕПЕРЬ ЭТА ГРАНИЦА БЫСТРО ОПУСТИЛАСЬ ВНИЗ НА СОТНИ МЕТРОВ ВНИЗ, СОГНАВ ВСЕХ ЖИТЕЛЕЙ СУШИ К НИЗМЕННОСТЯМ БЕРЕГОВОЙ ЛИНИИ ПАНГЕИ.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



ГАЗОГИДРАТЫ ИНИЦИИРОВАЛИ ГЛОБАЛЬНОЕ ПОТЕПЛЕНИЕ, ВЫЗВАВШЕЕ НАГРЕВ АТМОСФЕРЫ, ГИДРОСФЕРЫ И ЛИТОСФЕРЫ. В ИТОГЕ ПОЧТИ ВСЕ СУЩЕСТВА СУШИ И МОРЯ ПОЛУЧИЛИ ТЕПЛОВОЙ УДАР.

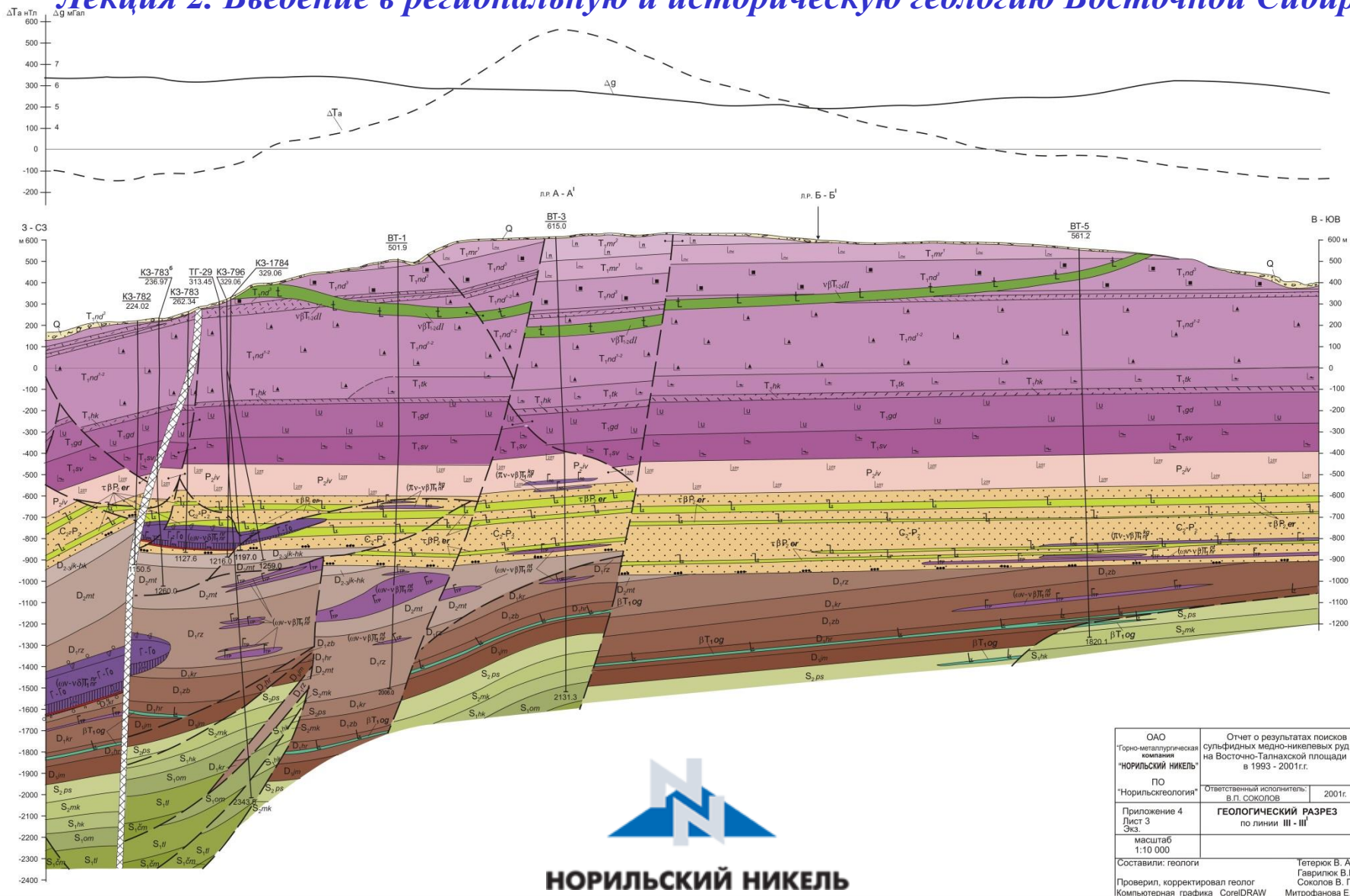
ВУЛКАНИЧЕСКАЯ ДЕЯТЕЛЬНОСТЬ НАСЫТИЛА АТМОСФЕРУ РАЗЛИЧНЫМИ СОЕДИНЕНИЯМИ ХЛОРА И СЕРЫ, ЧТО РАЗРУШИЛО ОЗОНОВЫЙ СЛОЙ. ЖЕСТКОЕ УЛЬТРАФИОЛЕТОВОЕ ИЗЛУЧЕНИЕ И СЕРНОКИСЛЫЕ ДОЖДИ ВЫЖИГАЛИ РАСТИТЕЛЬНОСТЬ И ЖИВОТНЫХ. НА ФОНЕ ЭТОГО АПОКАЛИПСИСА ВРЕМЕННО В БОЛЬШИХ КОЛИЧЕСТВАХ РАСПЛОДИЛИСЬ ГРИБЫ И ЛИШАЙНИКИ, БОЛЕЕ ТЕРПИМЫЕ К ТАКИМ ЭКСТРЕМАЛЬНЫМ УСЛОВИЯМ.



ВЕЧНАЯ МЕРЗЛОТА СИБИРИ ПРИ РАЗМОРАЖИВАНИИ НАСЫТИТ АТМОСФЕРУ МЕТАНОМ. МЕТАН В 20 РАЗ БОЛЕЕ СИЛЬНЫЙ ПАРНИКОВЫЙ ГАЗ, КОТОРЫЙ МОЖЕТ ПРИВЕСТИ К БЫСТРОМУ (НЕДЕЛИ-МЕСЯЦЫ) СКАЧКООБРАЗНОМУ ПОТЕПЛЕНИЮ.

Бермудский треугольник – место МГНОВЕННОГО исчезновения крупных судов вследствие всплытия огромных пузырей метана

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири



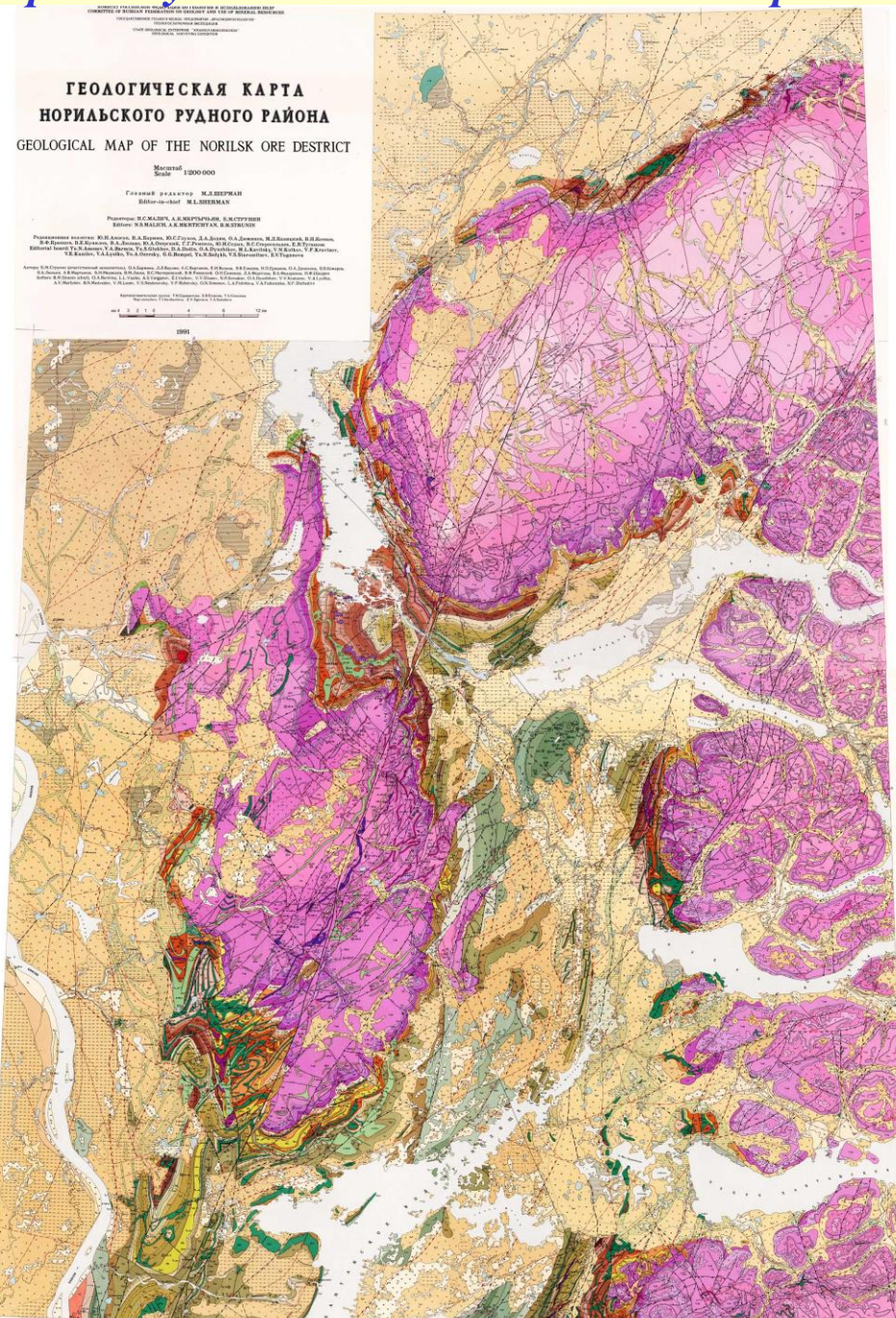
НОРИЛЬСКИЙ НИКЕЛЬ

ОАО "Горно-металлургическая компания "НОРИЛЬСКИЙ НИКЕЛЬ"	Отчет о результатах поисков сульфидных медно-никелевых руд на Восточно-Талийской площади в 1993 - 2001гг.	
по "Норильскгеология"	Ответственный исполнитель: В.П. СОКОЛОВ	2001г.
Приложение 4 Лист 3 Экз.	ГЕОЛОГИЧЕСКИЙ РАЗРЕЗ по линии III - III'	
масштаб 1:10 000		
Составили: геологи	Тетерюк В. А., Гаврилюк В. В.	
Проверил, корректировал геолог	Соколов В. П.	
Компьютерная графика CorelDRAW	Митрофанова Е.М.	

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Система и отдел	Литоология	Свита, индекс, мощность (м)	Позиция интрузивных комплексов
Q		(0-340)	
P-N			
J ₁ -K ₁		(0-1800)	
T ₁ -J ₁			
T ₁		Самоедская T _{1sm} (>600)	
		Кумгинская T _{1km} (160-210)	
		Хараелахская T _{1hr} (520-600)	
		Мокулаевская T _{1mk} (150-670)	
		Моронговская T _{1mr} (250-700)	
		Надеждинская T _{1nd} (150-570)	
		Туклонская T _{1tk} (0-220)	
		Хаканчанская T _{1hk} (1-370)	
		Гудчихинская T _{1gd} (0-350)	
		Сыверминская T _{1sv} (0-240)	
P ₂		Ивакинская P _{2iv} (0-300)	
C ₂ -P ₁		Тунгусская серия C ₂ -P ₂ (20-600)	
C ₁		Тундринская C _{1tn} (130-155)	
D ₃		Серебрянская C _{1sr} (15-40)	
		Ханельбринская C _{1hn} (65-80)	
D ₂		Фокинская D _{2fk} (220-500)	
		Каларгонская D _{2kl} (170-270)	
D ₁		Накохозская D _{1nk} (2-130)	
		Юктинская D _{1jk} (15-55)	
D ₀		Мантуровская D _{0mt} (90-500)	
		Разведочинская D _{0rz} (0-235)	
S ₂		Курейская D _{0kr} (50-60)	
		Зубовская D _{0zb} (100-150)	
S ₁		Хребтовская D _{0hr} (5-80)	
		Ямпактинская D _{0jm} (20-100)	
S ₀		Постническая S _{0ps} (75-120)	
		Макусская S _{0mk} (80-100)	
O ₂		Хюктинская S _{0hk} (70-130)	
		Омнутахская S _{0cm} (80-300)	
O ₁		Таликитская S _{0tl} (60-100)	
		Чамбинская S _{0cm} (120)	
O ₀		Загорнинская O _{2zg} (5-40)	
		Амараканская O _{2am} (20-50)	
C ₃		Гурагирская O _{2gr} (100-180)	
		Ильтыкская O _{2il} (600-800)	
C ₂		Уйгурская O _{2ug} (240-370)	
		Туколандинская C _{3tk} (350-520)	
C ₁		Чопкинская C _{3cp} (470-520)	
		Устьбрусская C _{3ub} (250)	
C ₀		Краснопоржская C _{3kp} (120)	
		Полбанская V-Cpl (550)	
V		Гремякинская Vgk (275)	
R		Рубнинская R _{3-vrb} (>720)	
		Черноореченская Rcr (500)	
PR		Медвежинская Rmd (1300)	
		Губинская Rgb (1000)	
PR		Плахинская (глины) Rph (>700)	
		Базальты, андезиты и риодациты	
PR		Лейкограниты	

Стратиграфическая колонка к геологической карте Норильского рудного района



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Норильский рудный район расположен в северо-западной части докембрийской Сибирской платформы вблизи ее современных границ с наложенными структурами мезозойско-кайнозойского возраста, относящимися к Западно-Сибирской плите и Енисейско-Хатангскому рифтогенному прогибу (Путеводитель, 1994).

По данным глубинных сейсмических исследований Норильский район характеризуется устойчивым трехчленным разрезом земной коры, состоящей из вулканогенно-осадочного чехла (мощностью от 3-5 до 13-15 км), верхнего (мощностью 10-14 км) и нижнего (мощностью 24-28 км) слоев консолидированной коры (Аветисов, 1984).

В разрезе чехла присутствуют карбонатно-терригенные отложения верхнего протерозоя, карбонатно-глинистые сульфатоносные толщи нижнего и среднего палеозоя, вулканогенные породы верхнего палеозоя и мезозоя, а также рыхлые образования мезозоя – кайнозоя.

Норильский район состоит из Дудинского и Хантайско-Рыбнинского валов на западе и востоке, сложенных осадочными породами верхнего протерозоя и нижнего палеозоя, а также Норильской, Волгочанской и Хараелахской мульдами, заполненными туфолоавовыми образованиями поздней перми - раннего триаса и отделяющиеся Имадино-Летнинским разломом от крупной структурной единицы - Тунгусской синеклизы (Рябов, 2001).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Платформенный чехол имеет в Норильском районе двучленное строение и составляет более 12 км. В его основании выделяются сложно дислоцированные, но слабо метаморфизованные осадочные и вулканогенные образования рифея общей мощностью около 3500 метров

Рифей:

1) серицит-хлоритовые сланцы плахинской свиты (Rph) мощностью более 700 метров,

2) красноцветные кварцитовидные песчаники губинской свиты (Rgb) мощностью 1000 метров,

3) доломиты медвежинской свиты (Rmb) мощностью 1300 метров и известняки,

4) доломиты и глинистые сланцы чернореченской свиты (Rcr) мощностью 500 метров

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Венд - нижний кембрий

- 1) рубнинская (Vrb, мощность более 720 метров)*
- 2) гремякинская (Vgk, мощность порядка 275 метров)*
- 3) полбанская (V-Є_{1pl}, мощность до 550 метров) свиты.*

В основании этих образований повсеместно наблюдаются пласты кварцевых песчаников и конгломератов.

Выше следуют ритмично-слоистые известняки и доломиты с прослоями мергелей и песчаников, последние фиксируют отдельные трансгрессивные микроциклы.

Общая мощность разреза постепенно уменьшается с запада на северо-восток от 1500 метров до 420-480 метров

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Краснопорожская свита (ϵ_1^{kr}) согласно перекрывает нижележащие отложения полбанской свиты и представляет собой глинисто-карбонатные породы с “клиньями” доломитовых фаций среди известняков с большим количеством органических остатков. В пределах северной части района, по материалам скважин Южно-Пясинской площади, мощность свиты не превышает 123 м.

Устьбрусская свита (ϵ_2^{ub}) майского возраста с трансгрессивным несогласием залегает на нижнекембрийских образованиях и складывается пестроцветной терригенно-карбонатной формацией с признаками меденосности и проявлена в бассейне Хантайки на севере района (Дюжиков, 1988). Мощность свиты меняется от 150 метров (р. Кулюмбэ) до 250 метров на юго-востоке территории.

Верхние кембрийские отложения представлены двумя свитами, перекрывающими с несогласием устьбрусские породы: нижней – чопкинской (ϵ_3^{cp}) и верхней – туколандийской (ϵ_3^{tk}) с равномерно уменьшающимися мощностями (от 520 м) к востоку - северо-востоку до 470 м и 350 м соответственно. Обе свиты относятся к сульфатно-терригенно-карбонатной формации. В первой из свит присутствует доманиковая фация с широким развитием олистолитовых образований, роль которых возрастает также к востоку.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Уйгурская свита (O_{1ug}) состоит из пестроцветных сульфатно-терригенно-карбонатных образований мощностью порядка 350 метров. Контакты с более древними кембрийскими и молодыми породами ильтыкской свиты согласные.

Ильтыкская свита (O_{1il}), в составе которой выделяются доломит-известняковые и глинисто-доломит-известняковые отложения, имеет мощность от 600 до 800 метров.

Гурагирская свита (O_{2gr}) близка по составу к предыдущим свитам и представляет собой пестроцветную сульфатно-карбонатно-терригенную с элементами песчано-кварцевой формации. Мощность свиты варьирует от 100 метров до 180 метров. Она согласно перекрывает подстилающие ильтыкскую свиту и со стратиграфическим перерывом перекрывается амарканской свитой.

Пестроцветная амарканская свита (O_{2am}) характеризуются существенно более высокой степенью "терригенности" по сравнению с более древними (аналогичными по составу) свитами и имеет небольшую мощность, до 50 метров.

Загорнинская свита (O_{2zg}) при выдержанности состава (мергели, аргиллиты и органогенно-детритовые известняки) непостоянна по мощности, которая колеблется в пределах 5-40 метров в зависимости от величины предсилурийского размыва. Контакт с нижележащей амарканской свитой согласный.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Чамбинская свита ($S_1\text{čm}$) среднеландоверийского возраста сложена граптолитовыми аргиллитами с прослоями органогенных известняков и конкрециями пирита. Мощность свиты достаточно выдержана по площади и составляет 100-130 метров. На более древних (ордовикских) отложениях она лежит с крупным стратиграфическим несогласием, но согласно перекрыта таликитской свитой.

Таликитская ($S_1\text{tl}$) и омнутахская ($S_1\text{om}$) свиты средне-верхнеландоверийского возраста относятся к глинисто-известняковой формации с преобладанием органогенных известняков. Мощность свиты 205-300 метров в районе Норильска и до 330 метров в бассейне реки Кулюмбэ (юг Норильского рудного района).

Хюктинская свита ($S_1\text{hk}$) венлокского яруса сложена массивными кораллово-строматопоровыми известняками, часто с желваками кремней, в верхах разреза - глинистыми желваковыми известняками с прослоями органогенных. В районе Норильска мощность ее колеблется в пределах 66-90 метров, в бассейне рек Кулюмбэ - до 130 метров. Контакт с ниже- и вышележащими образованиями согласный.

Макусская свита ($S_2\text{mk}$) лудловского возраста характеризуется сложной известняковой с элементами рифоидной формацией с повышенной доломитистостью и сульфатоносностью в верхней части разреза. Мощность свиты составляет 80-100 метров.

Постническая свита ($S_2\text{ps}$) конца лудлова образована неравномерно переслаивающимися известняками, доломитами, мергелями и ангидритами. На поднятиях (Дудинский и Хантайско-Рыбнинский валы) мощность пород свиты не превышает 75-80 метров, в зонах прогибов достигает 100-120 метров. Постническая свита согласно перекрывает нижележащие макуские отложения.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Ямпахтинская (D_{jm}) и хребтовская (D_{hr}) свиты представлены непрерывным разрезом однотипных карбонатных пород с многочисленными прослоями гипса и ангидрита, помимо которых в первой из свит иногда присутствуют линзы и гнезда целестина. Мощности свит 100 и 80 метров соответственно.

Зубовская свита (D_{zb}) сложена сероцветными доломитовыми мергелями, переслаивающимися с глинистыми доломитами, аргиллитами и ангидритами общей мощностью 100-150 метров. В Норильском районе местами отмечается несогласное залегание зубовской свиты на хребтовской свите.

Курейская свита (D_{kr}) представлена пестроцветными доломитистыми и известковистыми аргиллитами и мергелями с редкими прослоями алевролитов и известняков. Мощность во всех типах разреза остается практически постоянной и колеблется в пределах 50-60 метров. Контакты с ниже- и вышележащими образованиями согласные.

В составе разведочнинской свиты (D_{rz}) преобладают пестроцветные алевролиты, песчаники, гравелиты, образующие трансгрессивные микроциклы. Кроме того, свите свойственна значительная фосфатоносность и примесь пирокластического материала кислого состава. Мощность ее на поднятиях не превышает 110-150 метров, а в прогибах достигает 150-235 метров, причем к югу резко уменьшается вплоть до полного выклинивания.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Мантуровская свита (D_2mt) среднего девона с размывом залегает на отложениях разведочнинской свиты и представляет собой терригенно-карбонатный разрез с мощными соленосными толщами, большей части которых соответствуют каменные соли. Мощность свиты до 500 метров.

В юктинской свите (D_2jk) на поднятиях преобладают терригенно-карбонатные осадки мощностью от 12 до 40 метров, в прогибах – сульфатоносные мощностью до 55 метров. Контакты с подстилающей мантуровской свитой и вышележащими отложениями согласные.

Накохозская свита (D_3nk) верхнего девона сложена сульфатоносной глинисто-карбонатной пестроцветной формацией, мощность осадков которой на поднятиях 2-60 метров, в прогибах увеличивается до 80-130 метров.

Каларгонская свита (D_3kl) характеризуется мощным сероцветным терригенно-карбонатным разрезом, причем в прогибах преобладают доломиты, доломитовые мергели, доломитистые известняки и ангидриты. Мощность свиты составляет 170-270 метров. Каларгонская свита со стратиграфическим несогласием перекрывает более молодые накохозские отложения.

Фокинская свита (D_3fk) фаменского времени образована эвапоритовой сульфатно-терригенно-карбонатной толщей, которая сохранилась в основном в пределах прогибов и представлена ангидритами, мергелями доломитовыми с прослоями известняков, линзами каменных солей и глинисто-карбонатных брекчий. Мощность свиты 220-420 метров, реже 500 метров (западная часть Вологочанской мульды).

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Ханельбринская (C_1hn) и серебрянская (C_1sr) свиты турнейского яруса сложены обломочно-органогенными известняками, иногда с линзами кремней. В районе Норильска эти породы сохранились лишь в унаследованных прогибах, на остальной территории мощность их достаточно выдержана и не превышает 65-80 метров.

Тундринская свита (C_1tn) визейского возраста образована пестроцветными мергелями с прослоями гипсов и ангидритов, степень терригенности которых возрастает к северу, мощность их здесь не превышает 150 метров, на западе Норильской и Волгочанской мульды достигает 70-114 метров. Контакт с нижележащей толщей серебрянской свиты согласный.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

Тунгусская серия (C_2 - P_2) залегает на подстилающих породах нижнего карбона со значительным угловым несогласием, величина эрозионного вреза меняется до 1 км на расстоянии 5-10 км.

Тунгусская серия принадлежит угленосной лимно-паралической формации. По составу это песчаники различной степени зернистости, аргиллиты, алевролиты, гравелиты, редкие маломощные прослои конгломератов и пласты каменных углей до антрацитов.

Мощность отложений тунгусской серии сильно варьирует: от 20-40 метров на сводах валов до 600 метров в осевых частях прогибов.

В современной стратиграфической схеме тунгусская серия подразделяется на 7 свит: апсеканскую C_{2ap} (0-25 м), адылканскую C_{2-3ad} (0-80 м), руднинскую C_3-P_1rd (0-80 м), далдыканскую P_1dl (0-60 м), шмидтинскую P_2sm (8-65 м), кайерканскую P_2kr (15-85 м) и амбарнинскую P_2am (0-70 м). Все свиты разделяются в той или иной мере значительными размывами. Пласты каменных углей рабочей мощности имеются в далдыканской, шмидтинской и кайерканской свитах. В верхней части тунгусской серии появляется примесь пирокластического материала, наиболее значительная в амбарнинской свите.

Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

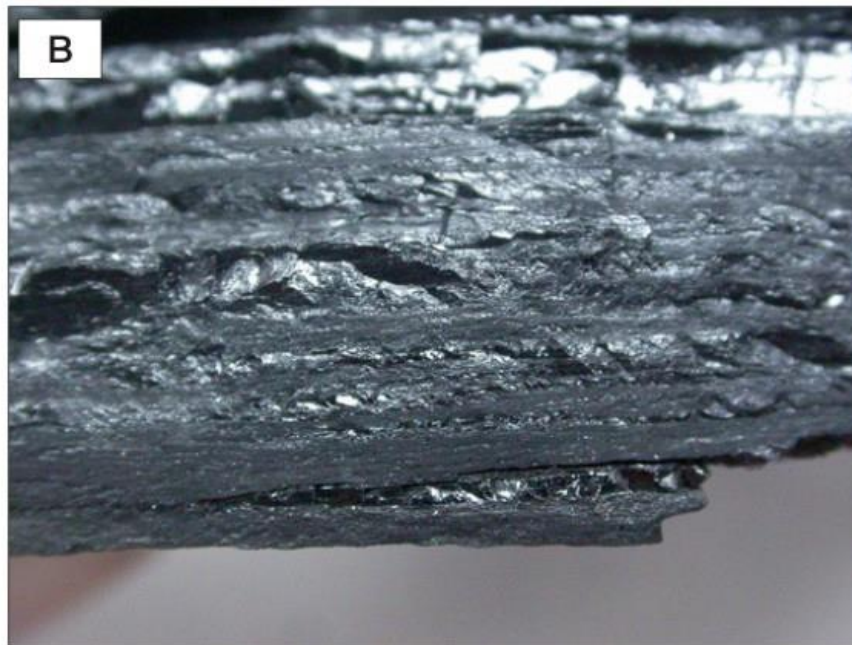


Породы тунгусской серии, представленные:

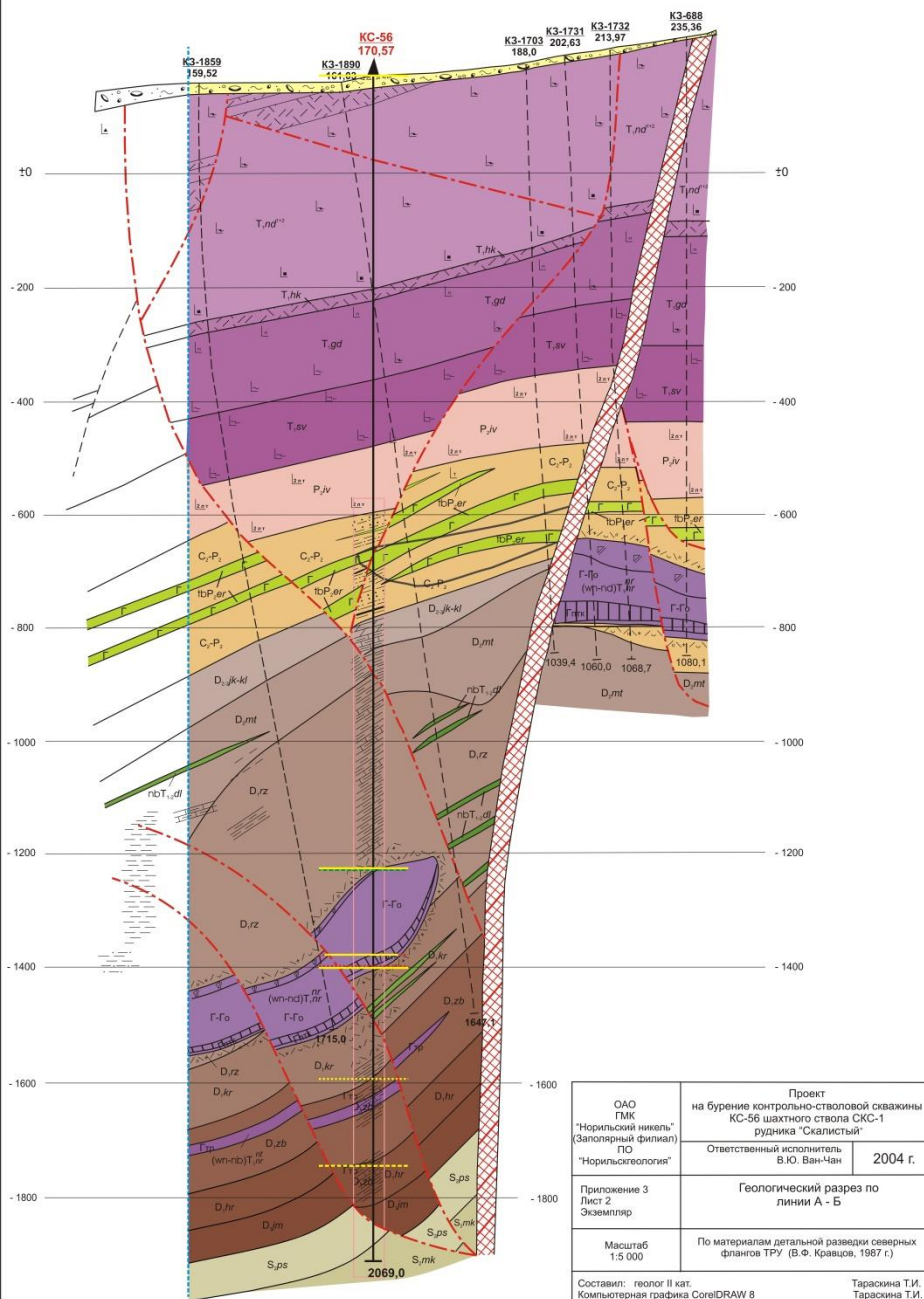
а - песчаниками различной зернистости,

б - аргиллитами (верхняя часть снимка) и гравелитами (нижняя часть снимка) (столбик керна скважины ОМ-6, соответствующий глубине 1074,0 метра, ширина керна на фотографии 52 мм),

в - антрацитами



Лекция 2. Введение в региональную и историческую геологию Восточной Сибири

[illegible]

ОАО Тяжелоемашинное «КОРЕЙСКОЕ АБББ»	Счет о результатах голосов участников акционерного общества на Бюджетно-Технической площадке 1999 – 2001гг.	
ГПО «Корейскиемашины»	100% акционер в.п. участия	100 %
Приложение 2 (лист 1 из 1)	Стратегическая компания	
	Составлено по информации о деятельности акционерного общества №3670, 99793 ГПО «Тяжелоемашинное»	
Составлен визитационная группа, СпецФАН	Министерство ВП Секторальных связей, СпецФАН	

Лекция 2. НГБ Северной Африки

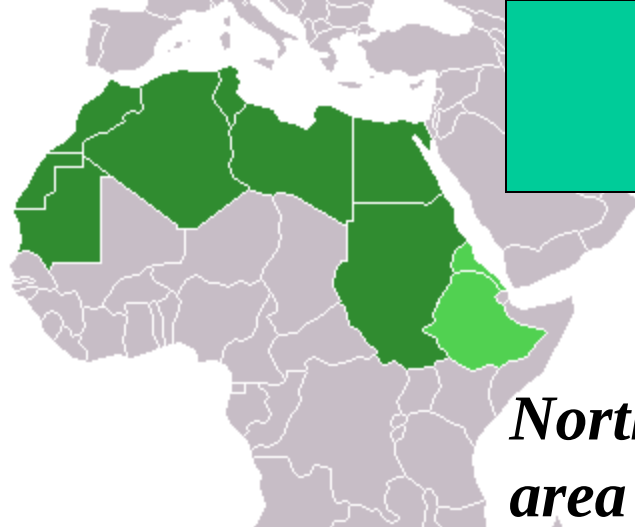
План

1. Введение в региональную и историческую геологию Северной Африки.

2. Палеогеография Северной Африки в фанерозое.

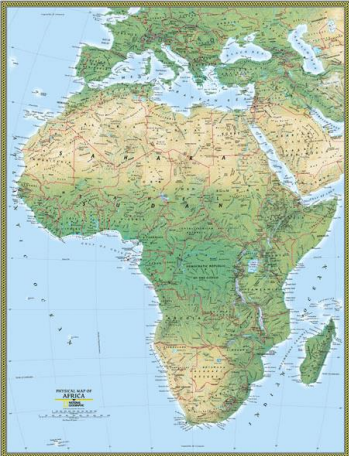


*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: введение*



*North Africa:
area of study*



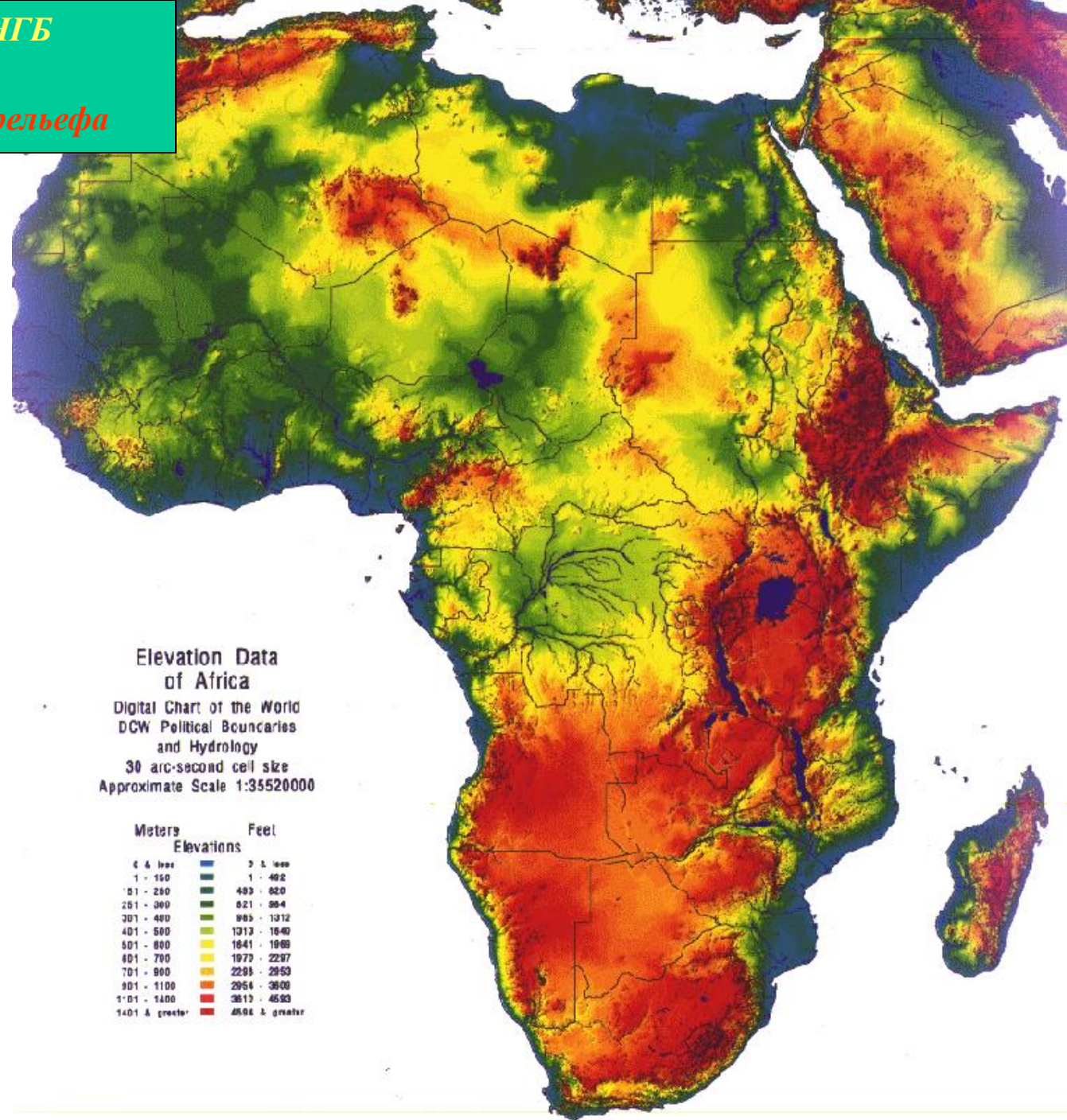


*Секвенции фанерозоя НГБ
Северной Африки*
Северная Африка: физическая карта

Physical map of North Africa



*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: карта рельефа*

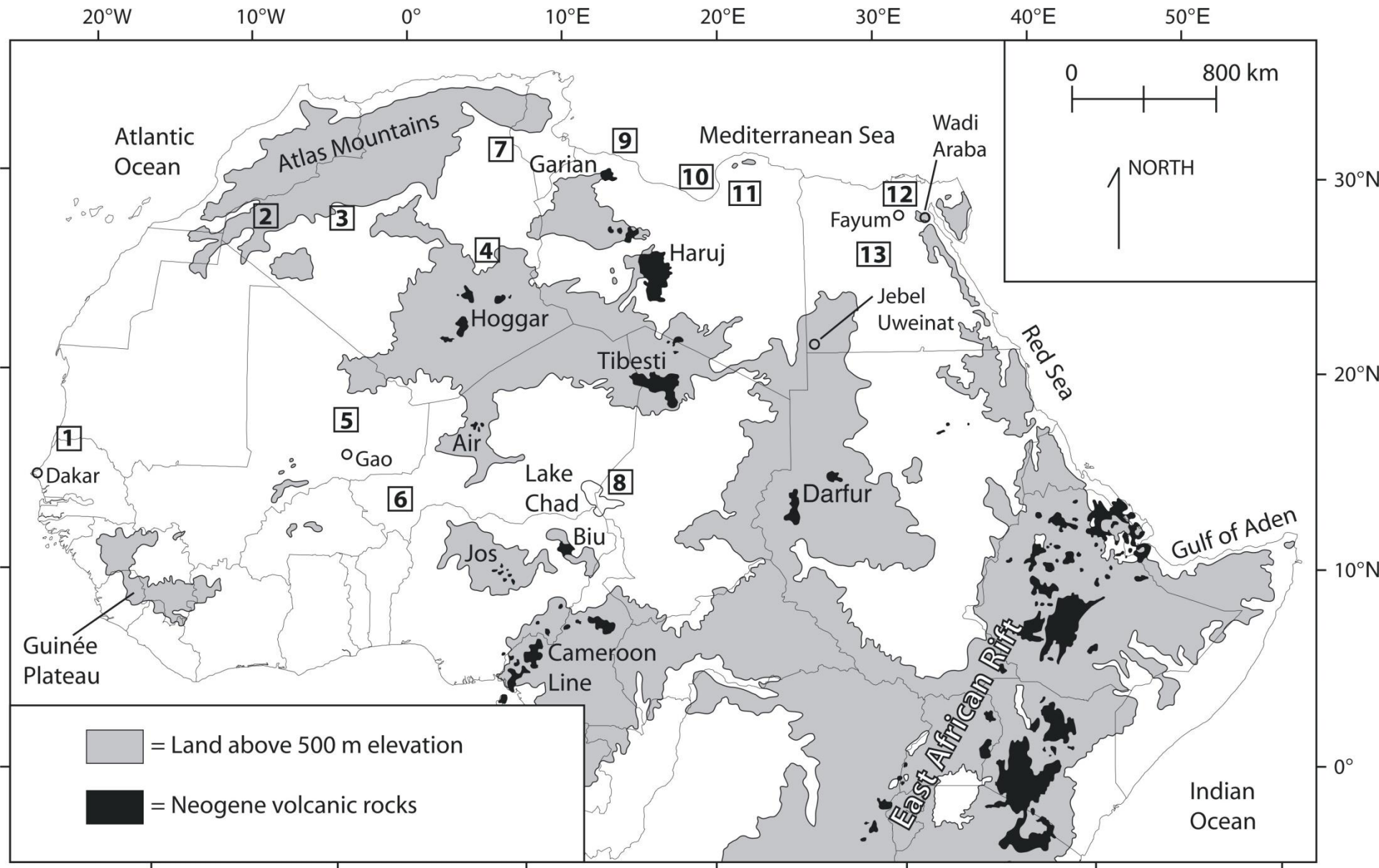


Relief of Africa

***lowlands -
transgression***

(sea covers the land)

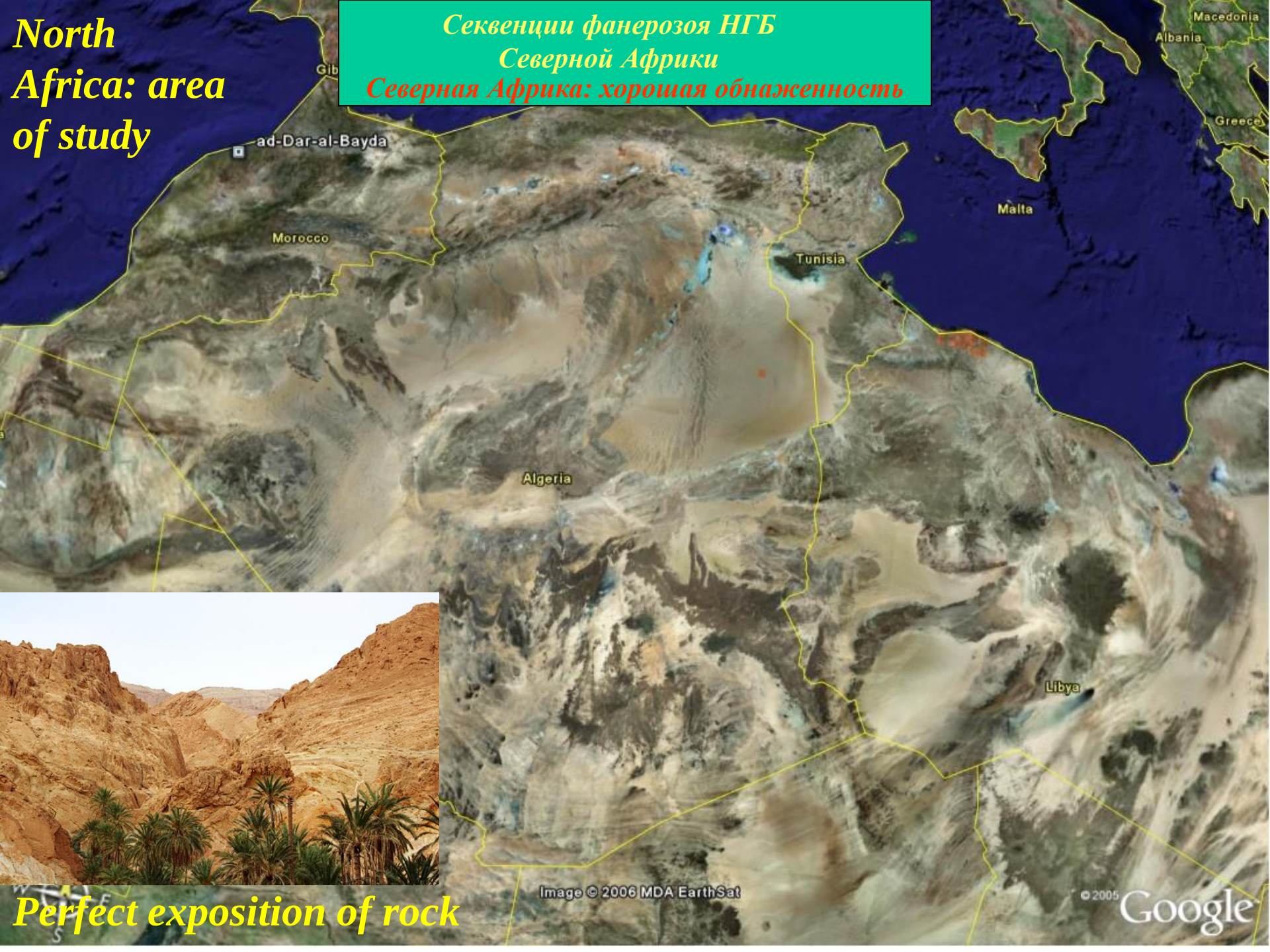
*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: карта рельефа*



Map of northern Africa showing topographic relief and the locations of selected Neogene volcanic rocks

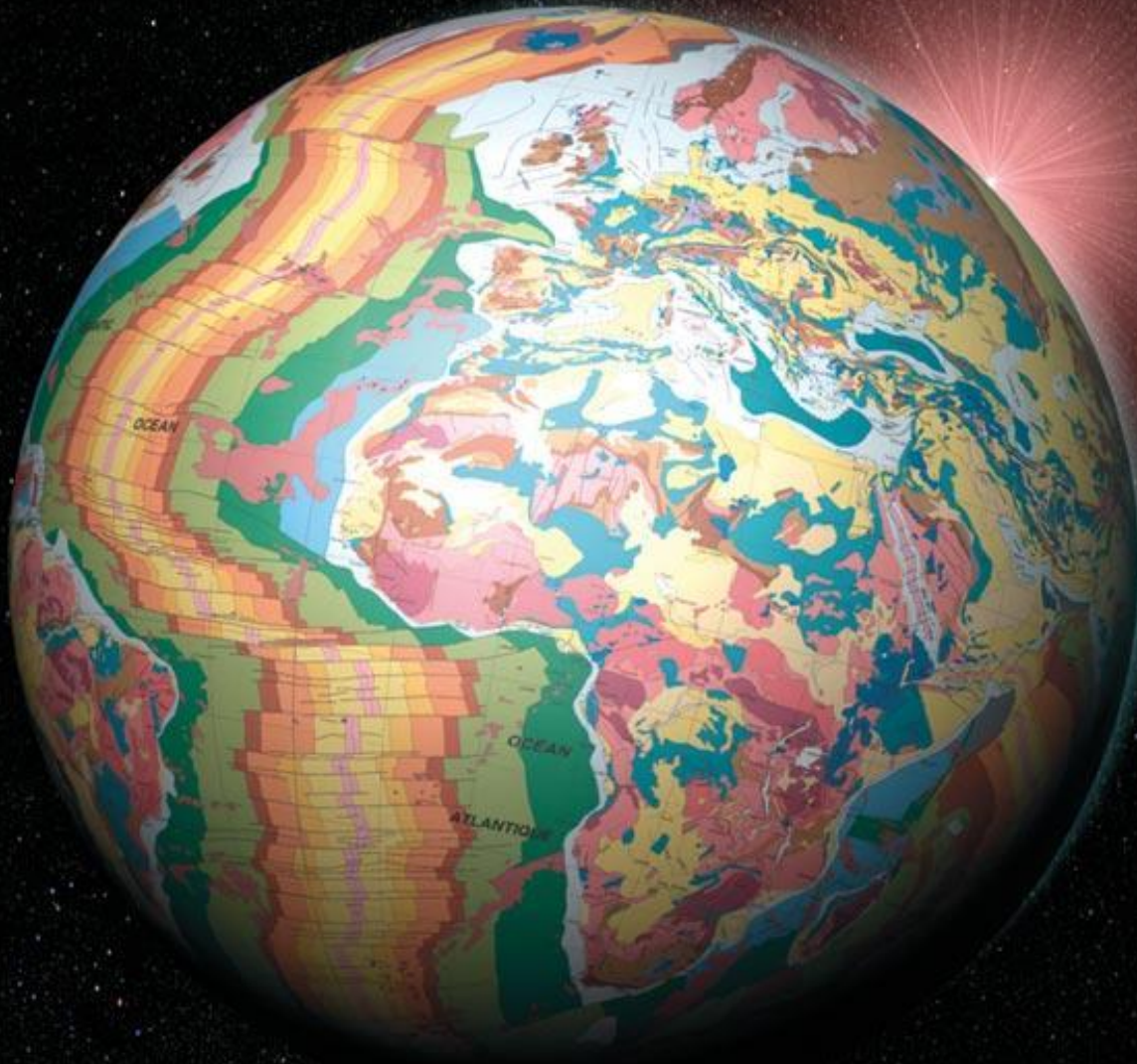
**North
Africa: area
of study**

*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: хорошая обнаженность*



Perfect exposition of rock

*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: геологическая карта*



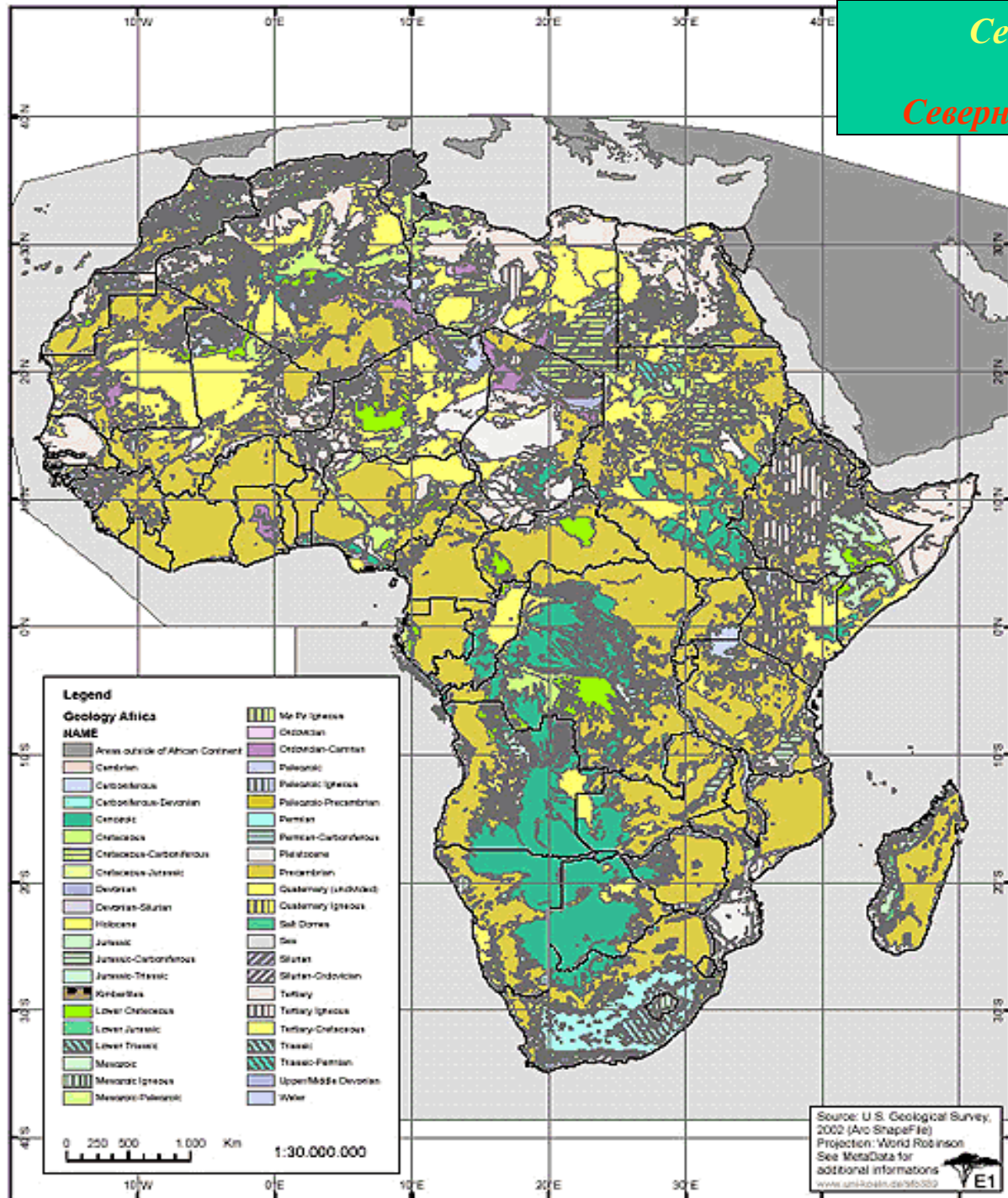
Bedrock geological map of Africa

*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: геологическая карта*



Geological map of Africa

*Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: геологическая карта*



Секвенции фанерозоя НГБ
Северной Африки
Северная Африка: геологическая карта

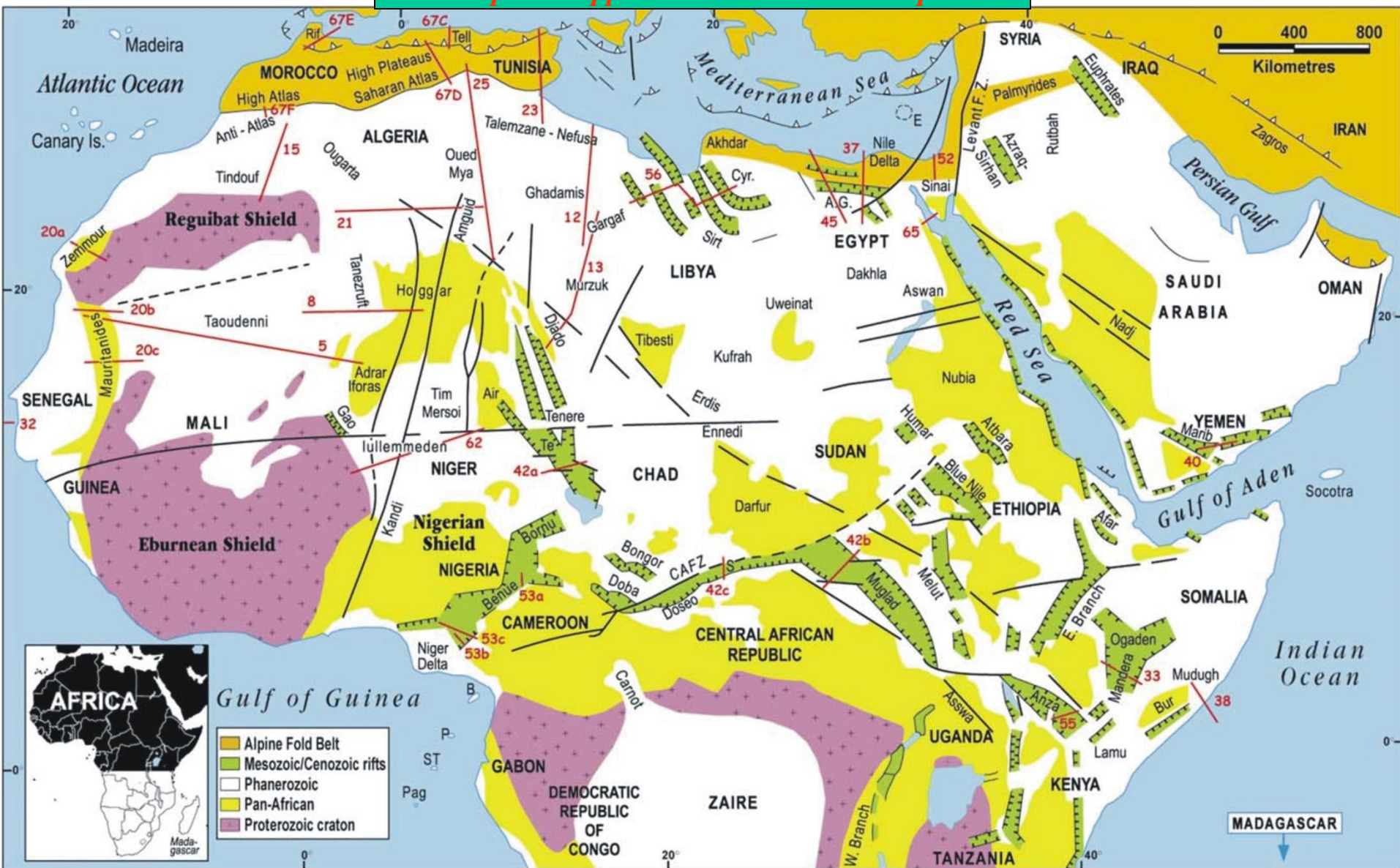
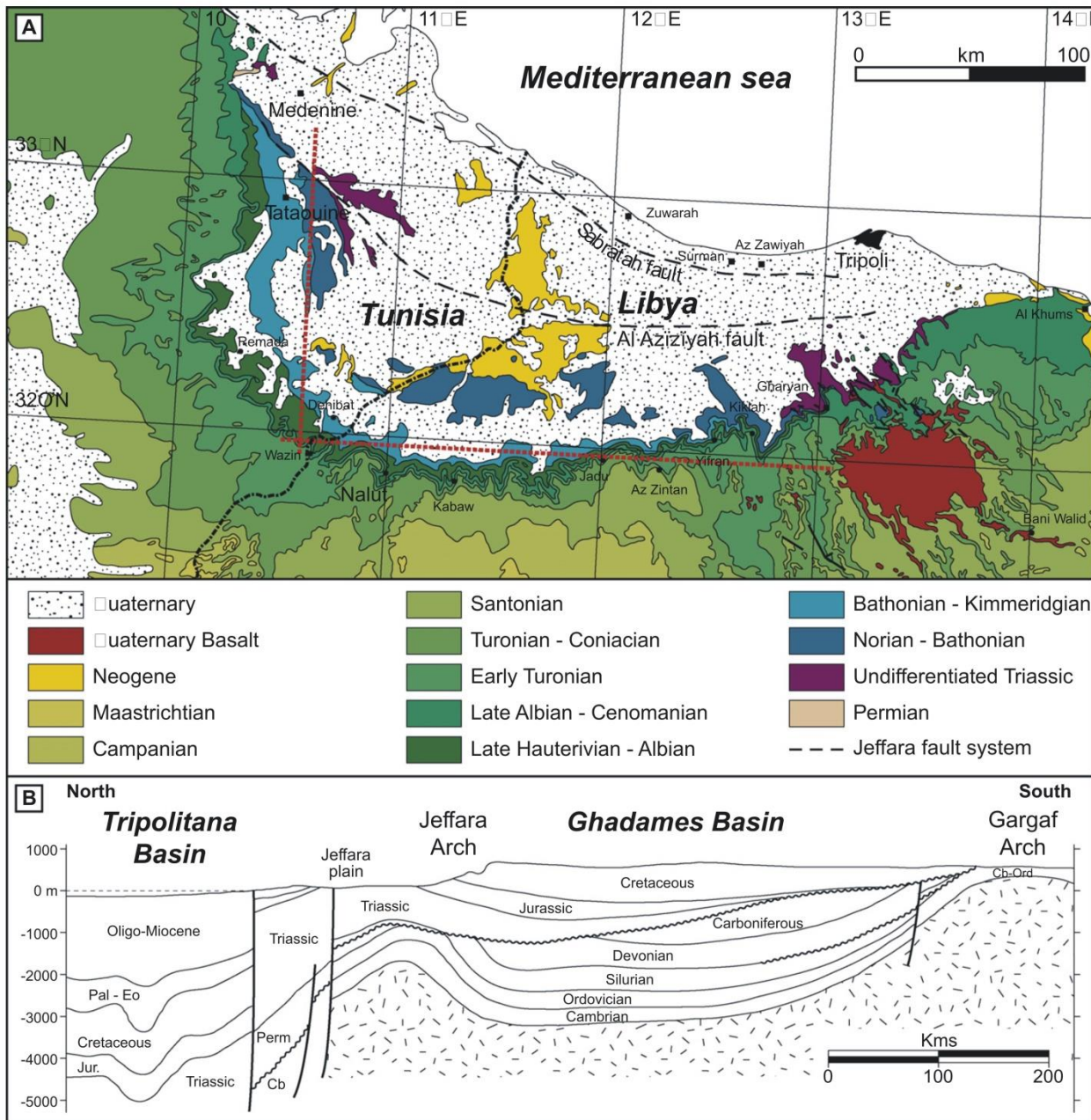


Fig . Schematic geological map of Northern Africa, Central Africa and Arabia

Legend: AG, Abu Gharadig; B, Bioko; CAFZ, Central African Fault Zone; Cyr, Cyrenaica; E, Eratosthenes Seamount; JP, Jos Plateau; P, Principe; Pag, Pagalu; S, Salamat; ST, São Tomé; Te, Termit.

Секвенции фанерозоя НГБ Северной Африки

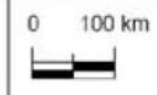
Северный Тунис и Ливия: геологическая карта



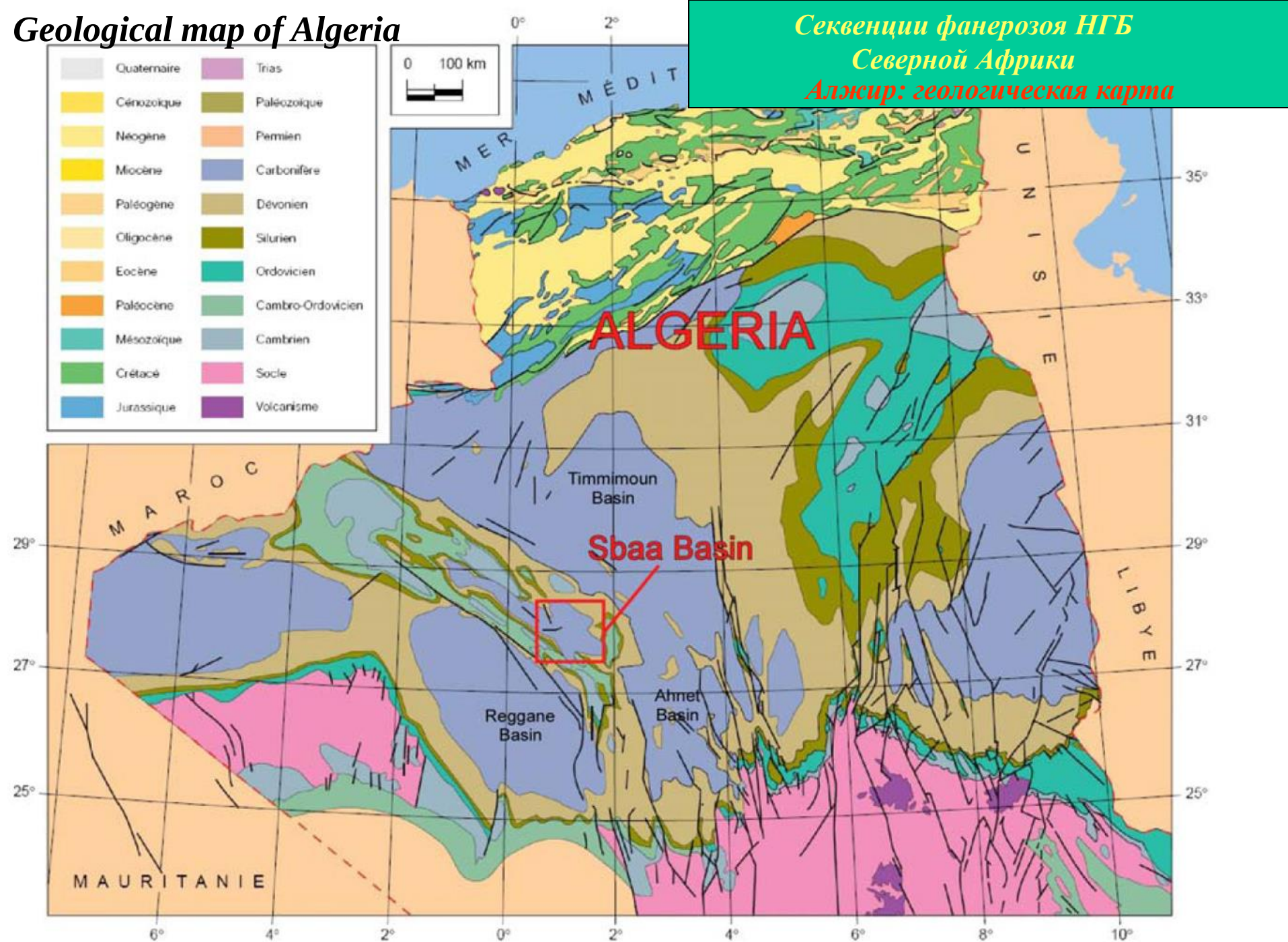
Geological map of Northern Tunisia and Libya

Fig. 2. (A) Geological map of the Jeffara escarpment. Modified from the geological map of Tunisia (scale 1/500 000) and the geological map of Libya (scale 1/1 000 000). The dashed red lines show the projection lines for the transects presented in Figs. 9 and 10. (B) North-south structural cross-section across the Tripolitania and Ghadames Basins in Libya (modified from Boote et al. (1998)).

Geological map of Algeria

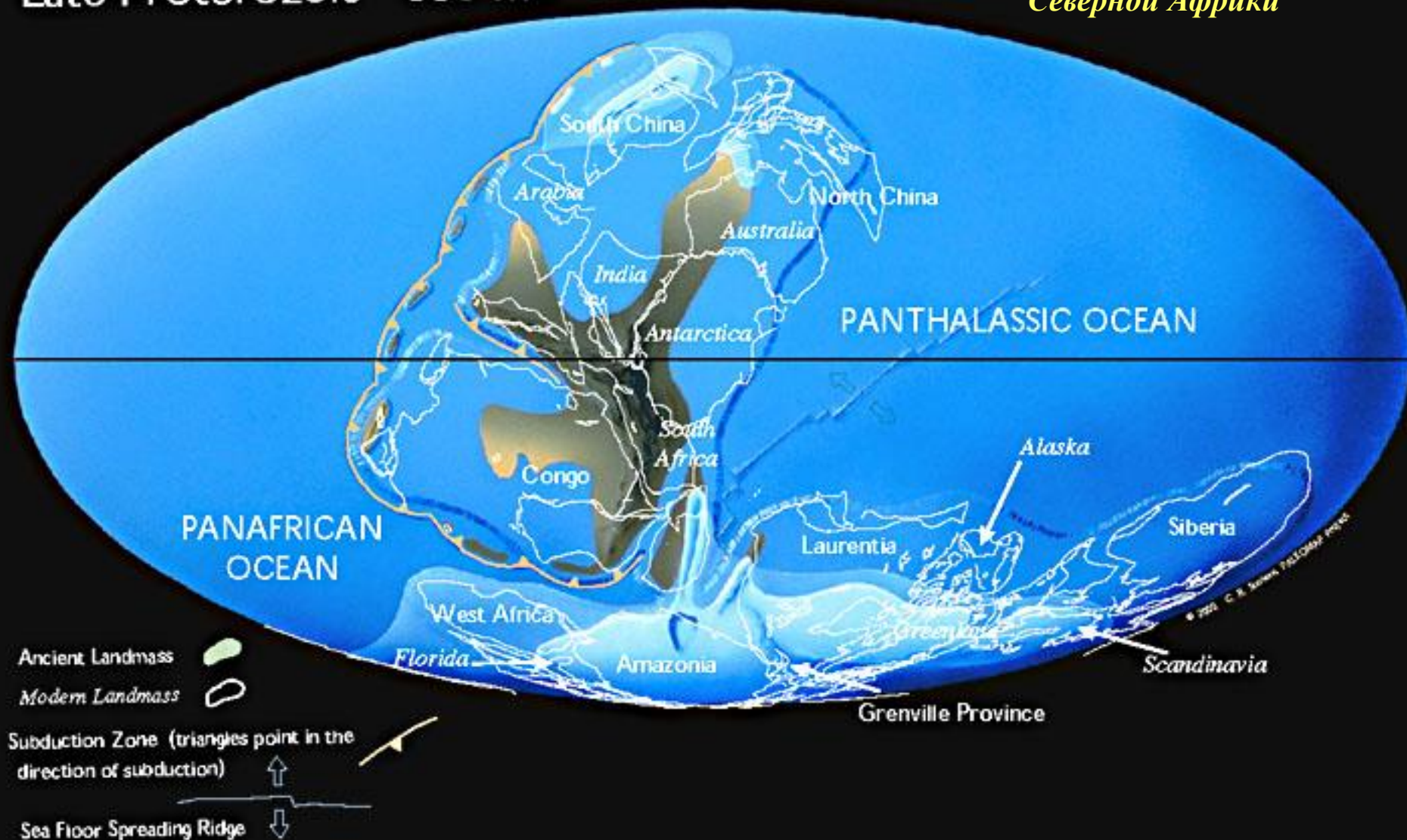


Секвенции фанерозоя НГБ
Северной Африки
Алжир: геологическая карта



Late Proterozoic 650 Ma

Секвенции фанерозоя НГБ
Северной Африки



Paleogeography in mobilistic style

Секвенции фанерозоя НГБ Северной Африки

На протяжении всего палеозоя в южном полушарии существует единый суперконтинент - Гондвана, площадь которого последовательно наращается.

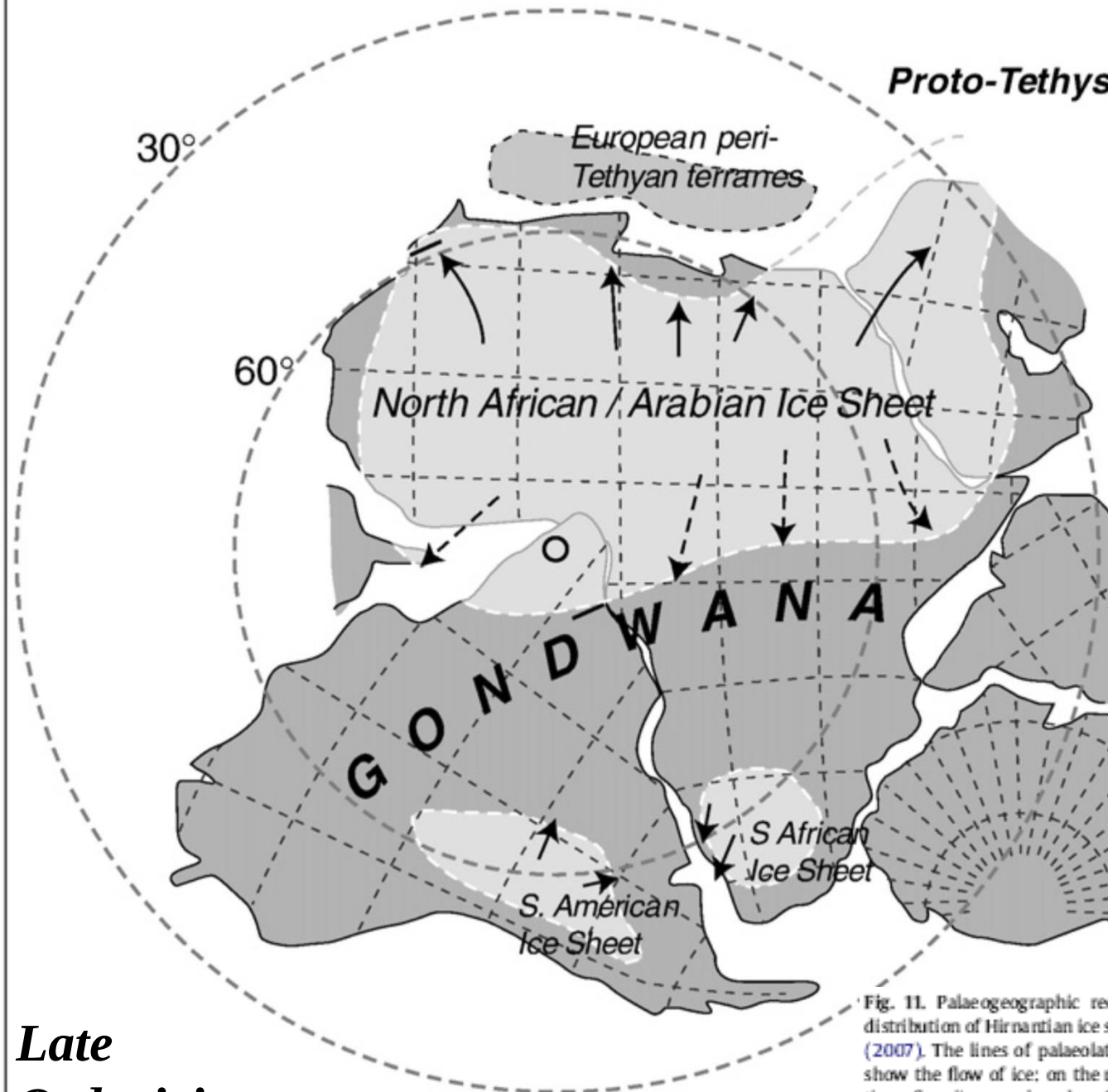
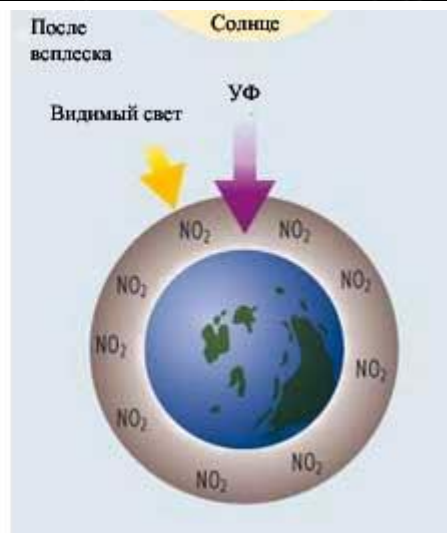


Fig. 11. Palaeogeographic reconstruction of Gondwana at ~440 Ma showing the distribution of Hirnantian ice sheets. The distribution of ice sheets is after [Ghienne et al. \(2007\)](#). The lines of palaeolatitude are after [Stampfli and Borel \(2002\)](#). Solid arrows show the flow of ice: on the northern margin of the North African/Arabian ice sheet, these flow lines are based on field observations, whereas on the southern margin (sub-Saharan Africa) they are hypothetical as Hirnantian strata are not exposed.

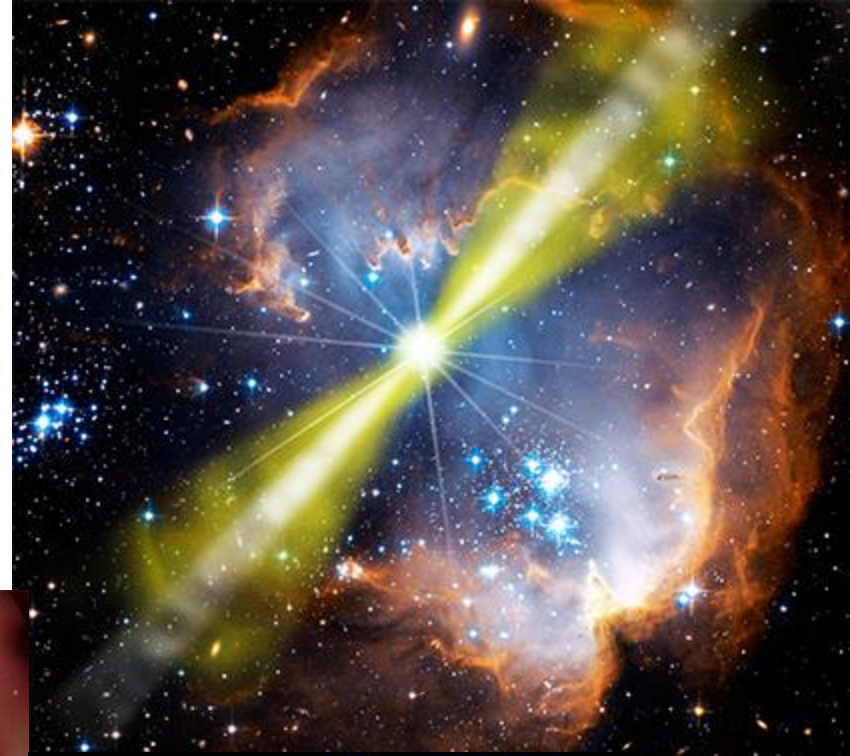
**Late
Ordovician**



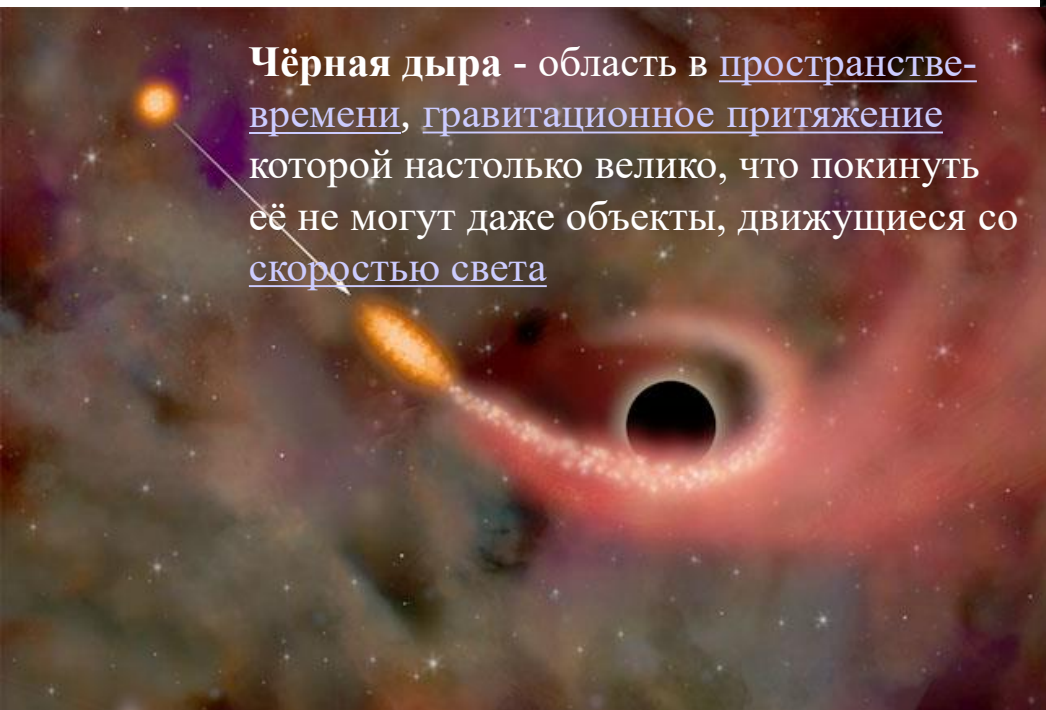
Массовое вымирание организмов в конце ордовикского периода (443 млн. лет назад) может быть объяснено мощным гамма-всплеском, произошедшим в относительной близости от Солнечной системы. Вымерло 2/3 биологических видов и 85% живых существ, 60% морских организмов. Такой взрыв порождает два смертельных пучка гамма-лучей, направленных в противоположные стороны. Они движутся со скоростью света. Мощный поток гамма-излучения достиг атмосферы Земли и за 10 секунд наполовину разрушил озоновый слой, на восстановление которого потребовалось не менее 5 лет. Животные и растения сгорели, как долго загорающий на солнце человек. Возможные на тот момент примитивные жители суши (грибы, мхи, лишайники, черви) погибли за секунды, а обитатели мелководья и верхних слоев открытого океана (пелагиали) – за минуты. Смерть планктона (основы, или начала пищевой цепи), а также рифостроящих и сопряженных с ними существ вызвала коллапс всех пищевых связей. Таким образом, гамма-всплеск сделал обитателей Земли беззащитными перед ультрафиолетовой радиацией Солнца. Однако, это вымирание растянулось во времени.

Началась перестройка атмосферы. Высокоэнергетичные гамма-лучи разбивают молекулы атмосферного азота (N_2) на отдельные атомы, которые вступают в реакцию с молекулярным кислородом (O_2), в результате чего получается окись азота (NO), которая разрушает озон (O_3) и дает диоксид (двуокись) азота (NO_2) – бурый почти непрозрачный удушливый газ. NO_2 с атомарным кислородом опять же дает NO , разрушающую все больше озона. Небо затягивает тучами азот-содержащих газов, которые препятствуют проникновению солнечного света. Гамма-всплеск спровоцировал похолодание, т.е. ледниковый период (animal.discovery.com).

Гамма-всплеск – масштабное космическое событие электромагнитной природы с выбросом энергии взрывного характера длительностью от миллисекунд до часа. За первоначальным всплеском следует “послесвечение”, излучающее на более длинных волнах (рентген, ультрафиолет, оптическое, инфракрасное и радио). *Причина:* трансформация сверхновой в черную дыру или слияние двух нейтронных звезд. За несколько секунд в результате взрыва высвобождается объем энергии, эквивалентный 10 млрд лет “работы” Солнца



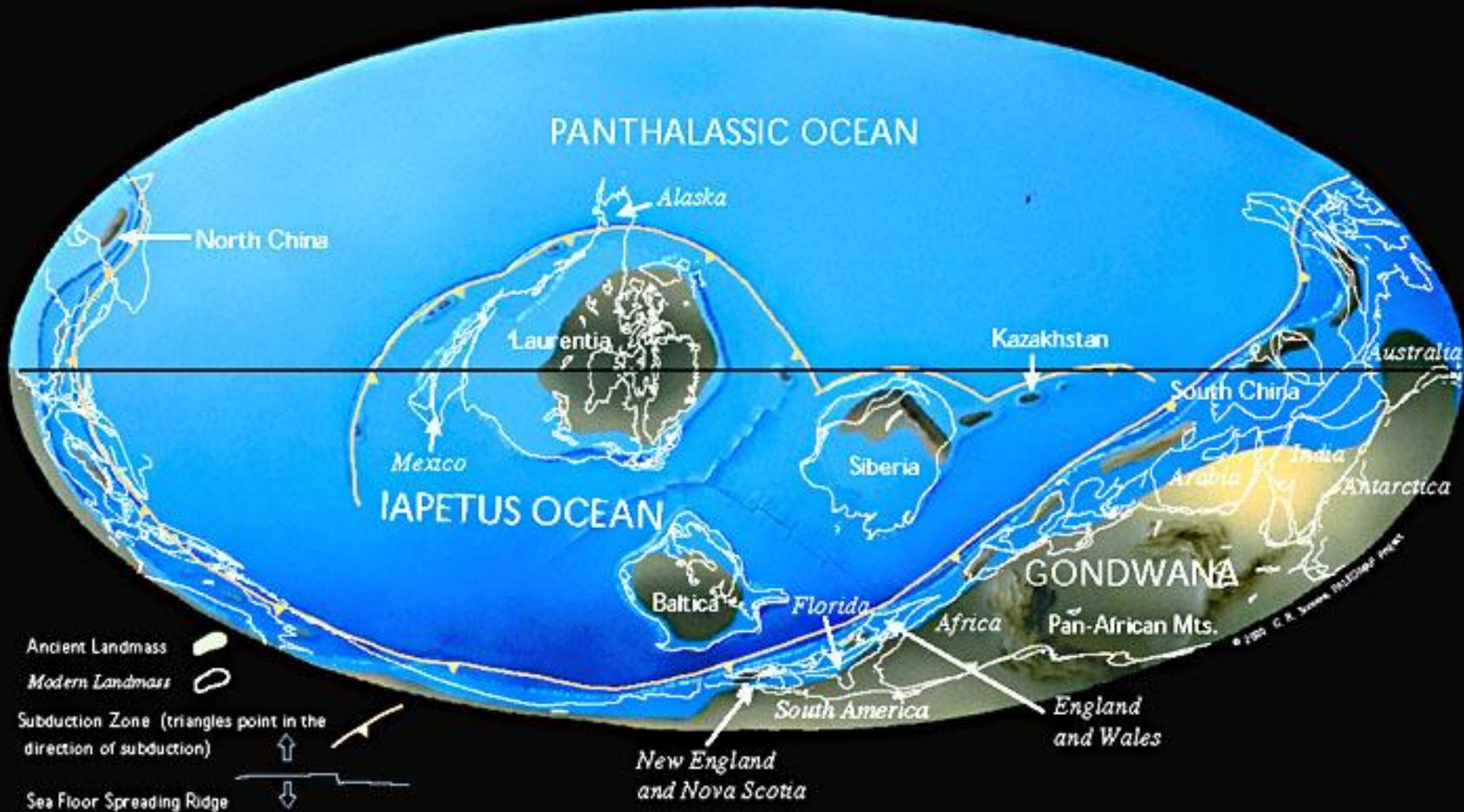
Чёрная дыра - область в пространстве-времени, гравитационное притяжение которой настолько велико, что покинуть её не могут даже объекты, движущиеся со скоростью света



Нейтронные звезды представляют собой огромные скопления нейтронов; их масса близка к массе Солнца, диаметр – $2 \cdot 10^5$ диаметра Солнца, плотность порядка 10^8 т/см³.

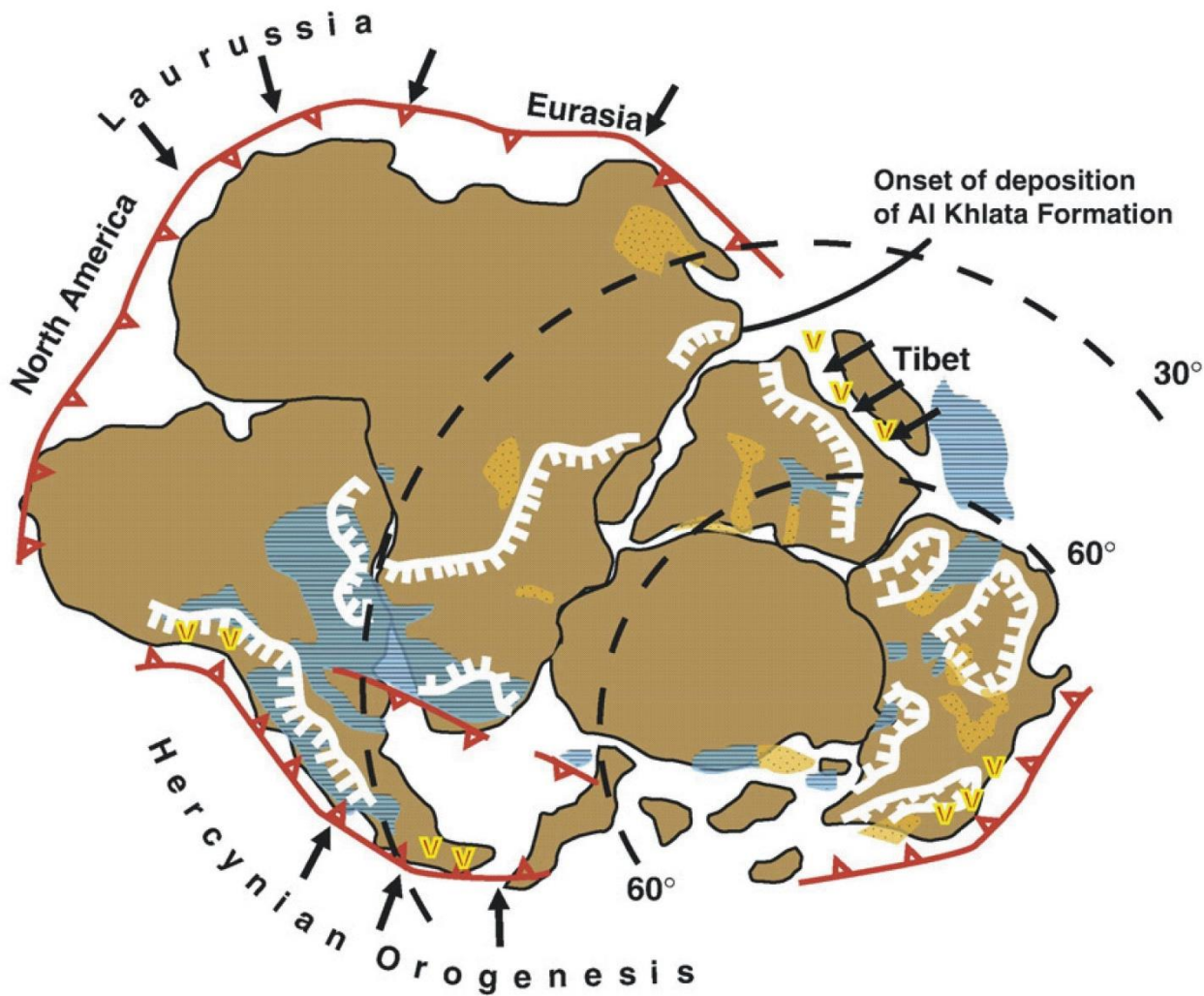
Late Cambrian 514 Ma

*Секвенции фанерозоя НГБ
Северной Африки*

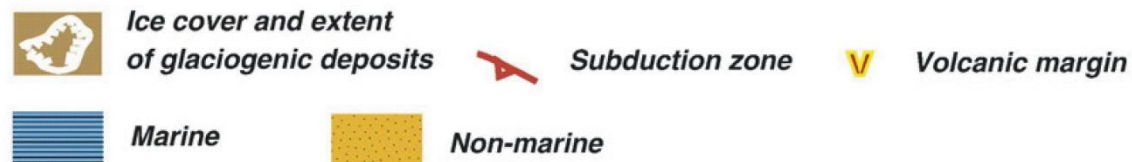


Paleogeography in mobilistic style

Секвенции фанерозоя НГБ Северной Африки



D.P. Le Heron et al. / Earth-Science Reviews 93 (2009) 47–76

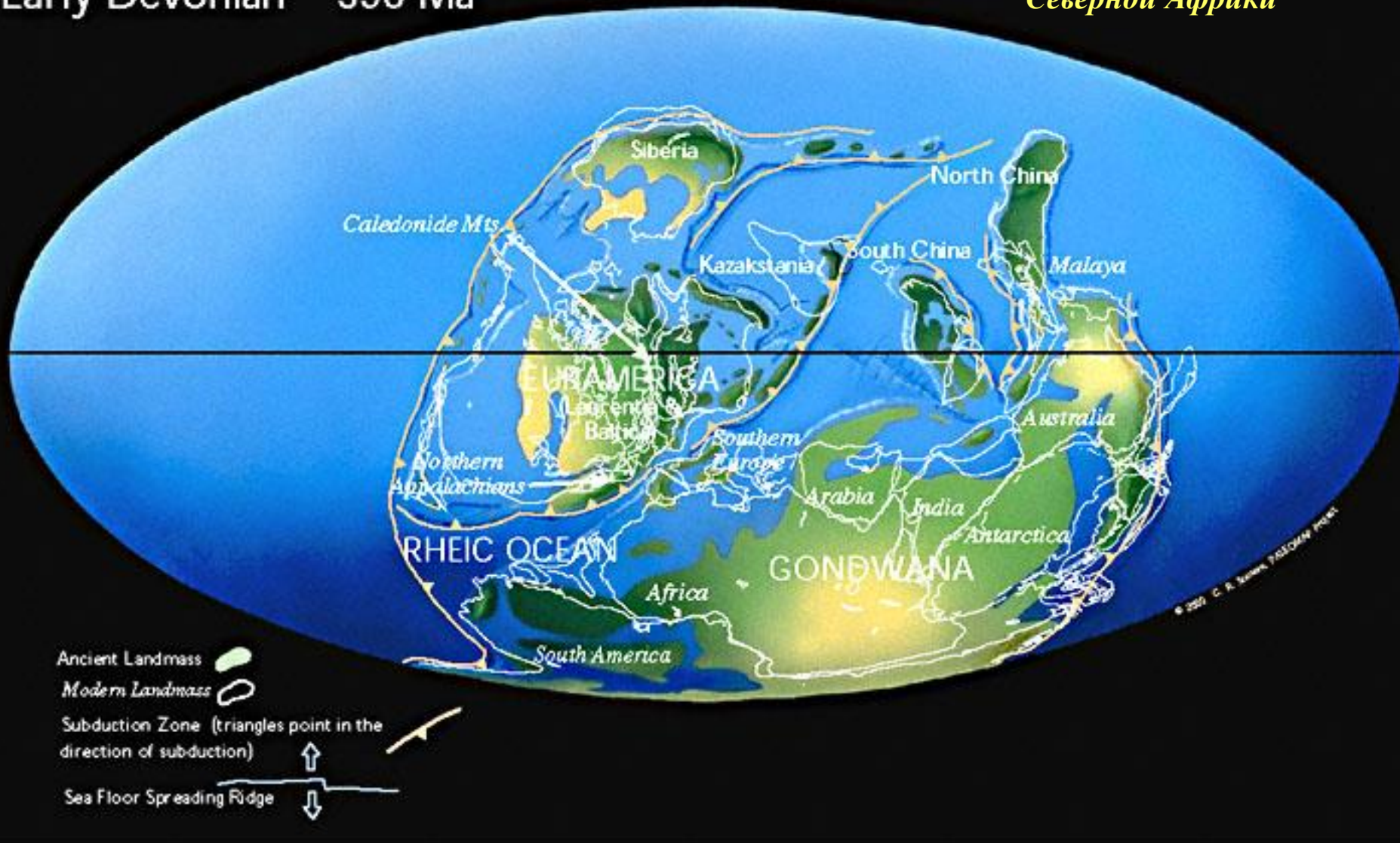


Palaeogeography of Gondwana during the Pennsylvanian. The initiation of Late Palaeozoic ice cover was broadly time transgressive, passing from modern day west (South America) to east (Australia) (Note that ice cover became established at mid palaeo-latitudes in Oman; ice sheets were absent further west in North Africa probably as a result of this latter area occupying low palaeo-latitudes and/or subdued relief.

Pennsylvanian

Early Devonian 390 Ma

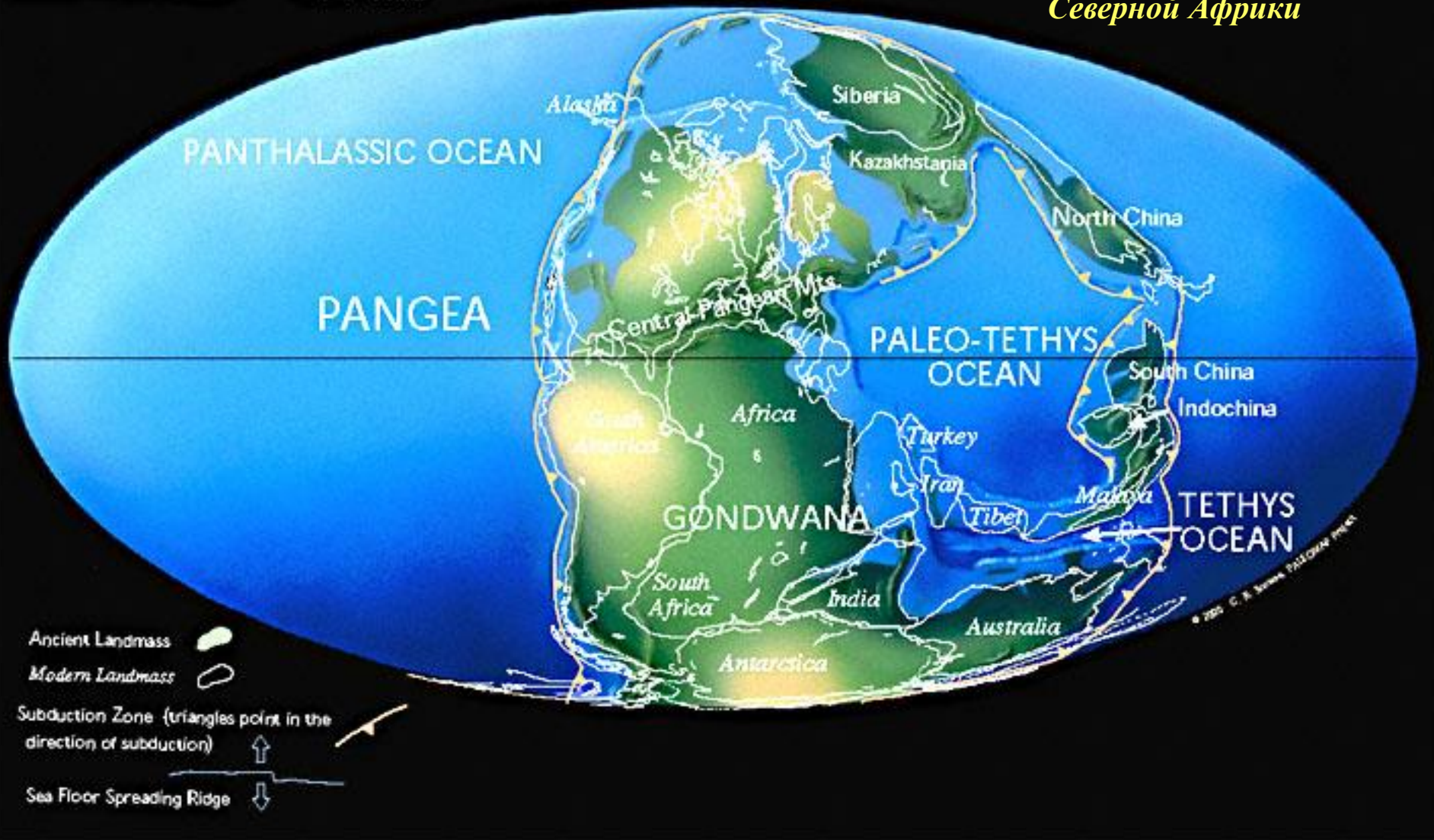
*Секвенции фанерозоя НГБ
Северной Африки*



Paleogeography in mobilistic style

Late Permian 255 Ma

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Paleogeography in mobilistic style

В конце Pz - начале Mz – Пангея II и впадина Палеотихого океана, от которой внутрь Пангеи II вдавался «залив» юго-восточной части Палеотетиса. По краям впадин Тихого океана продолжалось непрерывное развитие окраинно-континентальных геосинклинальных поясов.

С начала T, а во многих местах с начала J – возрождение Среднеземноморского геосинклинального пояса на всем его протяжении. Разделение Пангеи II на Лавразию и Гондвану.

С середины J – возникновение и последовательное расширение впадин молодых океанов: Атлантического, Индийского и Северного Ледовитого.

Таким образом, в Mz – одновременно существовали:

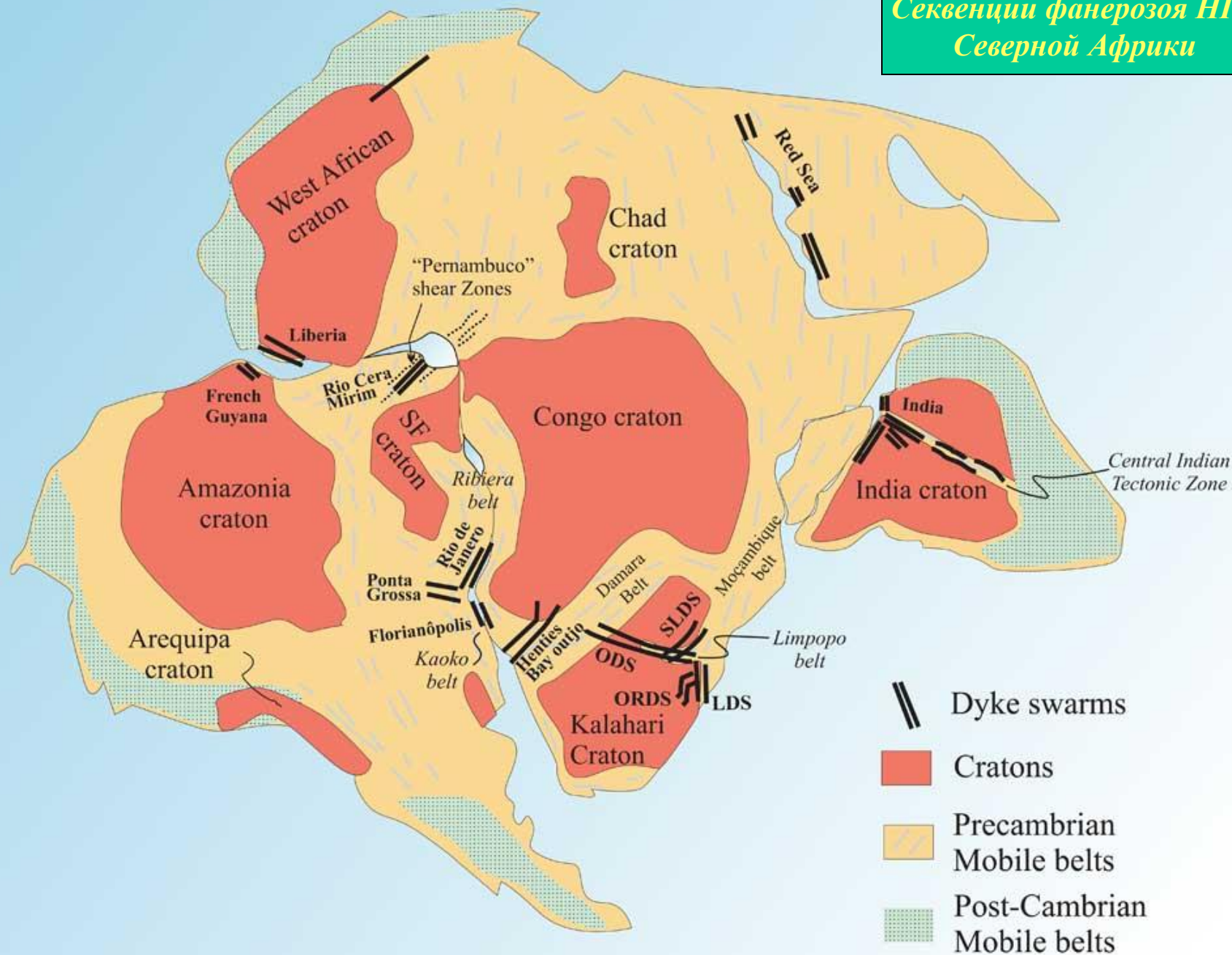
- 1) Континентальные массивы Лавразии и Гондваны
- 2) Геосинклинальные (подвижные) пояса:

Средиземноморский (между Лавразией и Гондваной),

Окраинно-континентальные пояса Тихоокеанского кольца

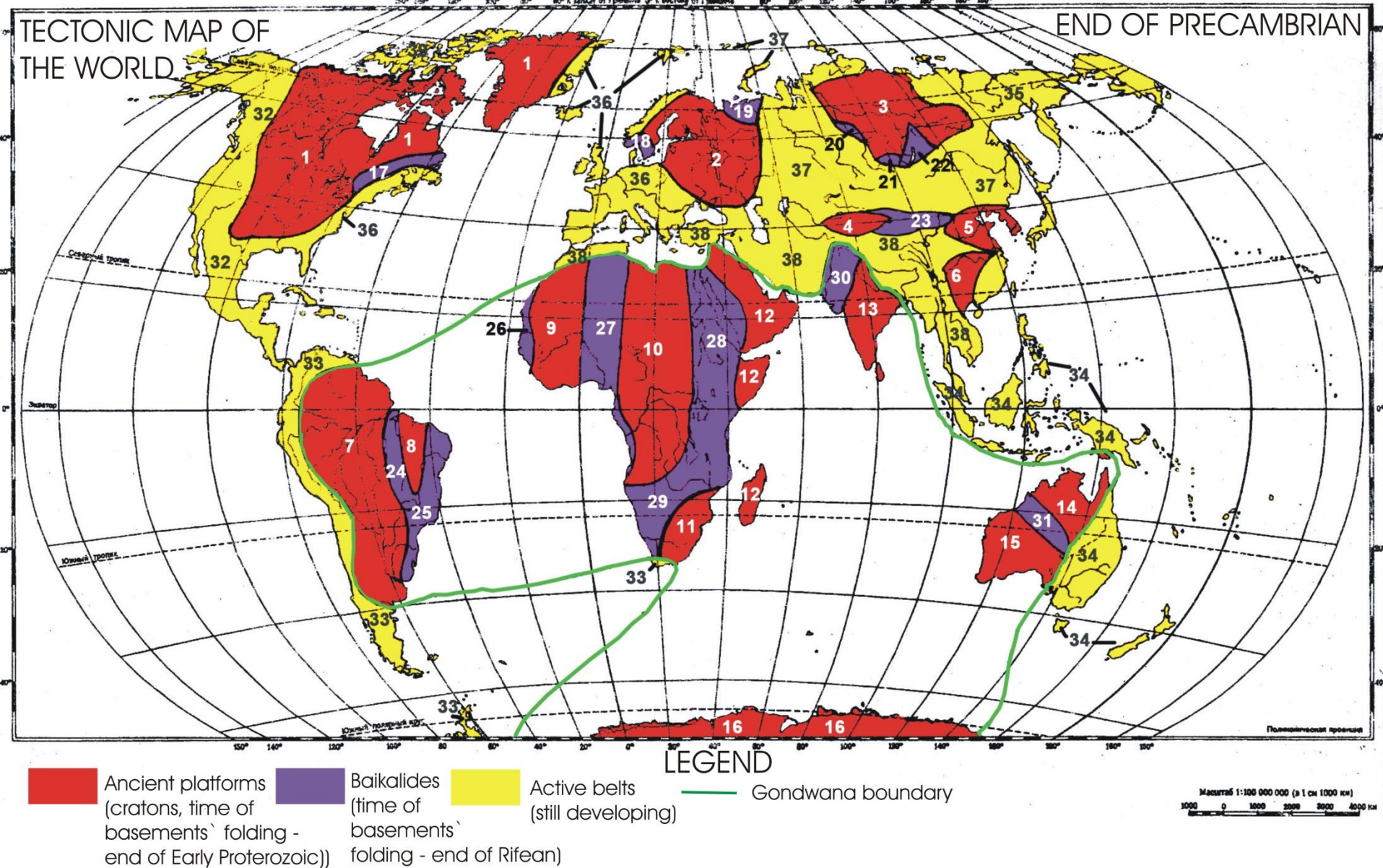
- 3) Тихоокеанические впадины: унаследованная (Тихий океан) и новообразованные

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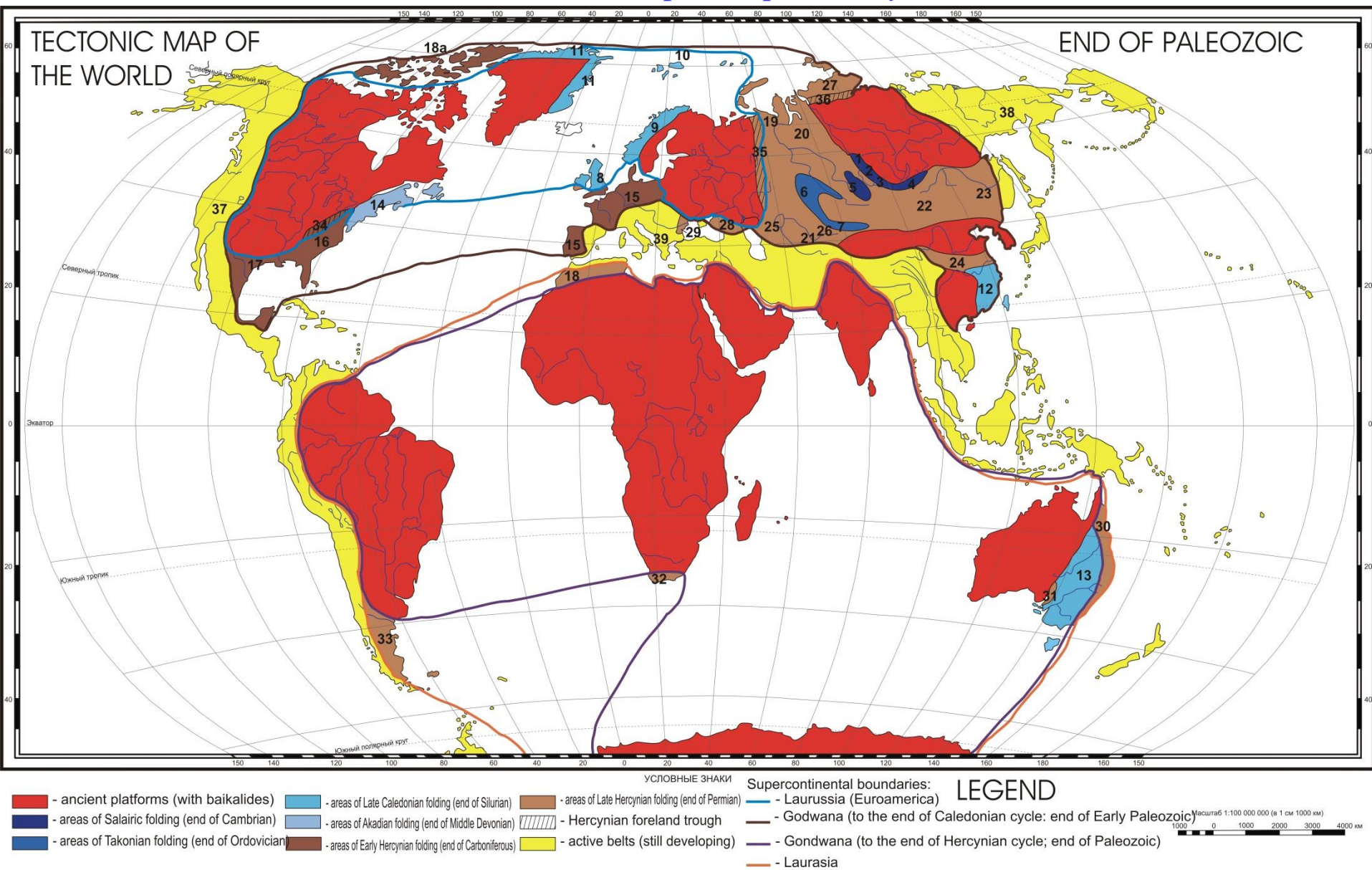
Палеотектоническая карта мира к концу кембрия



Paleogeography in fixistic style

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Палеотектоническая карта мира к концу палеозоя



Paleogeography in fixistic style

Секвенции фанерозоя НГБ Северной Африки

В отличие от Лавразии, Гондвана к началу МЗ – единый континентальный, почти исключительно платформенный массив, существовавший с начала РЗ.

1. Начало МЗ

Продолжение РЗ этапа.

Вся Гондвана приподнята.

На этом фоне - завершение развития некоторых впадин Гондванского типа (Карру, Индостанских, Мараньян)

Т - отложены во всех впадинах – пестроцветные песчано-глинистые отложения с эоловыми песчаниками. Южный Аридный пояс.

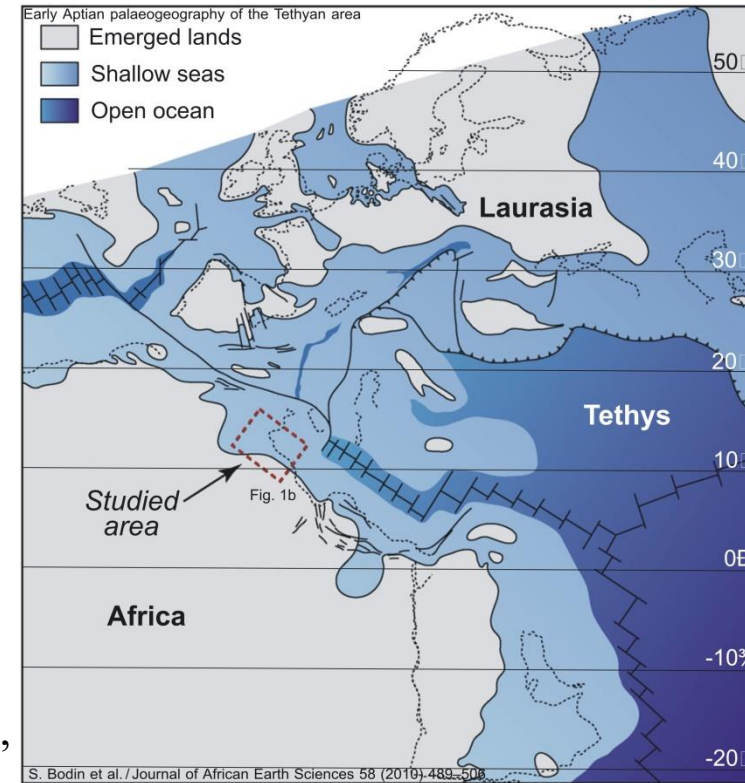
Ј₁₋₂ отложения- песчано-глинистые ,сероцветные, местами угленосные.

Завершается развитие впадин интенсивным проявлением траппового магматизма: наземные излияния базальтовых лав, внедрение силлов и даек. Огромные мощности (в Паранской впадине до 1800м).

Возраст трапповой формации – Т₃ - Ј₁ в Южной Америке и Южной Африке

Ј₃-К₁пс в Индии

Сходство с Тунгусской синеклизой.



В конце К – начале Р - возникновение и очень быстрое развитие Декканской впадины. Последняя впадина Гондванского типа. Грандиозные проявления траппового магматизма (мощность формации до 2000 м).

2. Вторая половина МЗ (J-K) и далее в КЗ

Формирование более молодых, обширных плоских впадин, заполняющихся в основном континентальными отложениями во внутренних частях приподнятых южных платформ.

Амазонская синеклиза и др. впадины в Бразилии – с K_1al

Впадина Конго J₃-K

Большой Артезианский бассейн – с J

Заполняются песчано-глинистыми отложениями. Изредка – кратковременные трансгрессии моря.

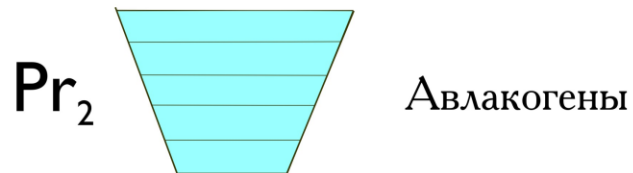
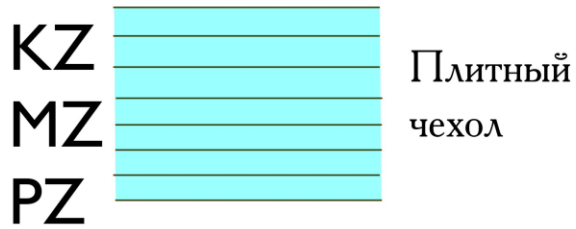
По форме - как синеклизы или небольшие плиты.

PZ и MZ₁ этап – аналог авлакогенной стадии на северных платформах.

MZ₂ и далее K₂ этап- аналог плитной стадии на северных платформах.

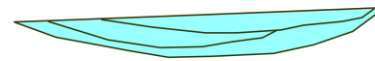
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Северные

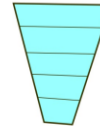


Фундамент

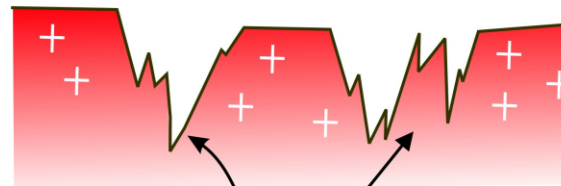
Южные



Плитный чехол



Впадины Гондванского
типа

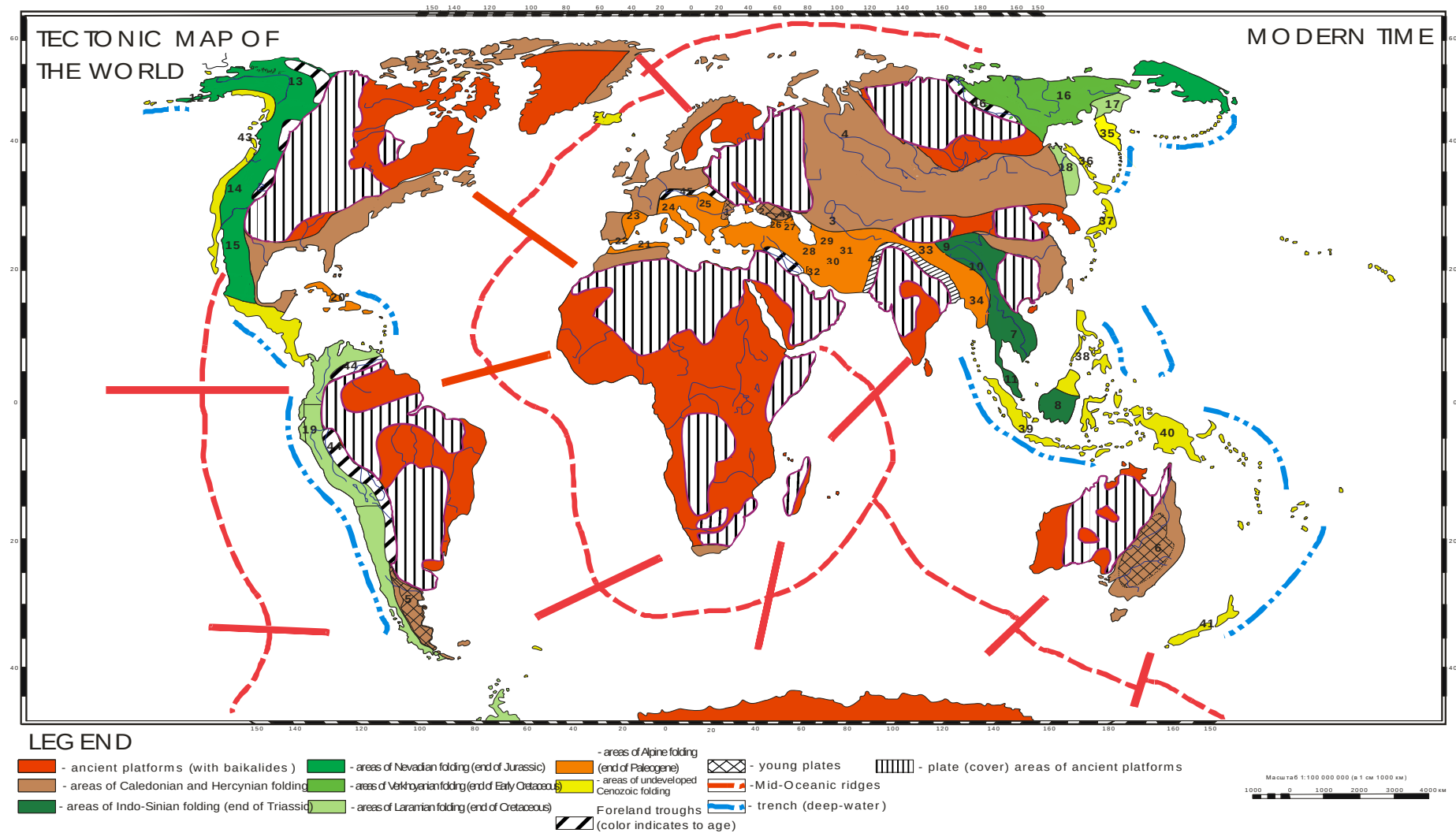


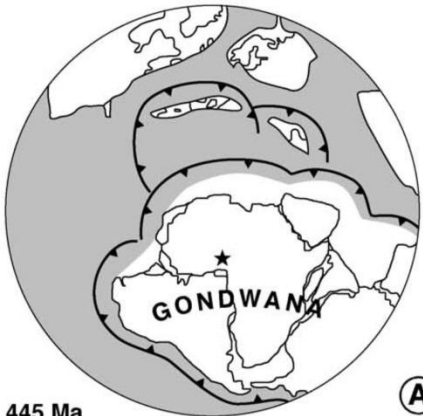
Малые геосинклинальные
пояса



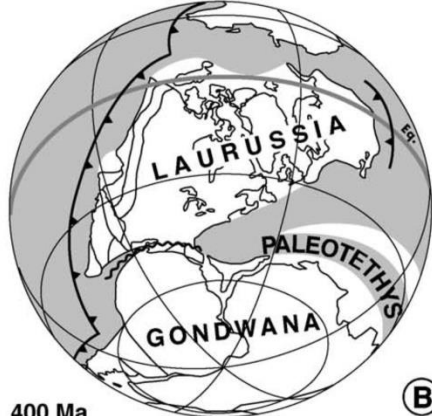
Секвенции фанерозоя НГБ Северной Африки

Тектоническая карта мира





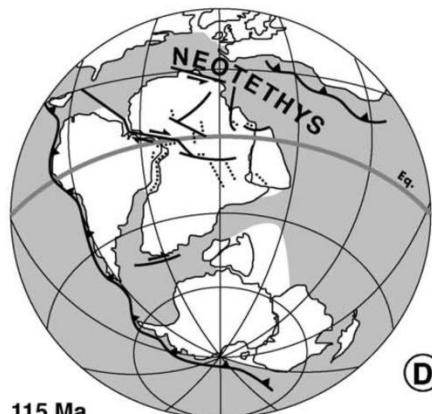
**445 Ma
latest Ordovician**
black star shows the South Pole position



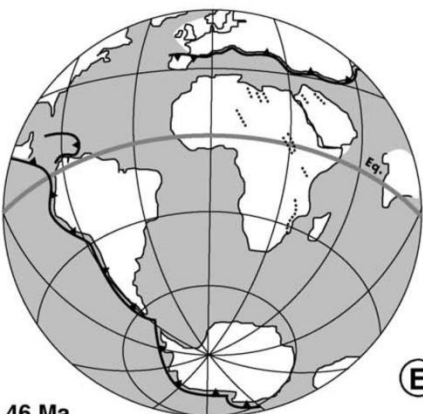
**400 Ma
Early Devonian**



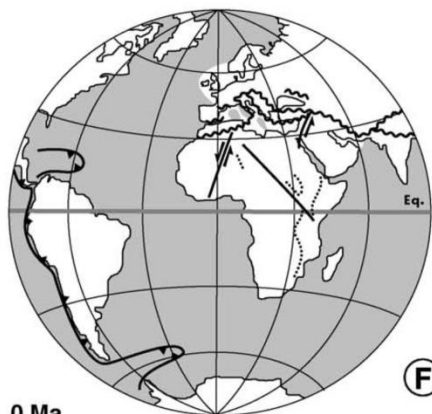
**220 Ma
Late Triassic**



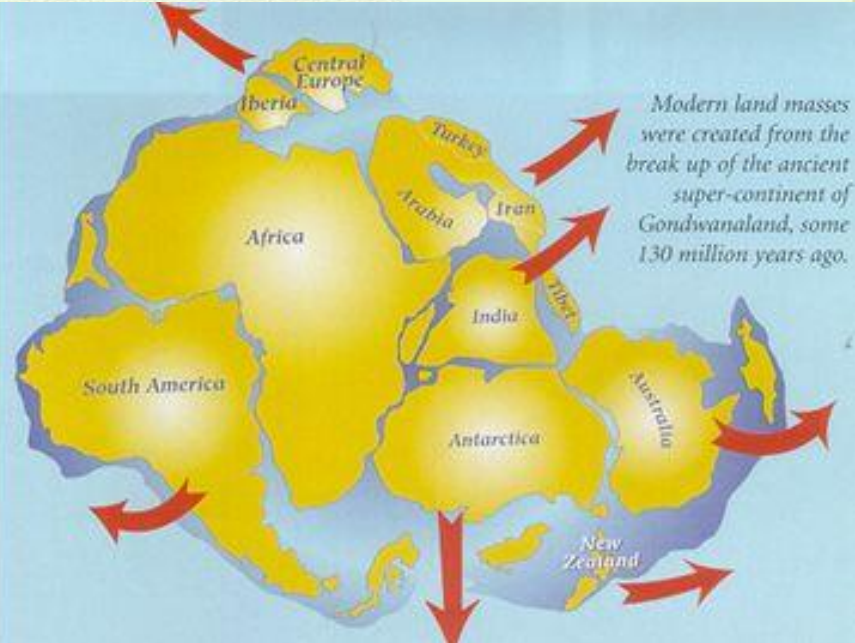
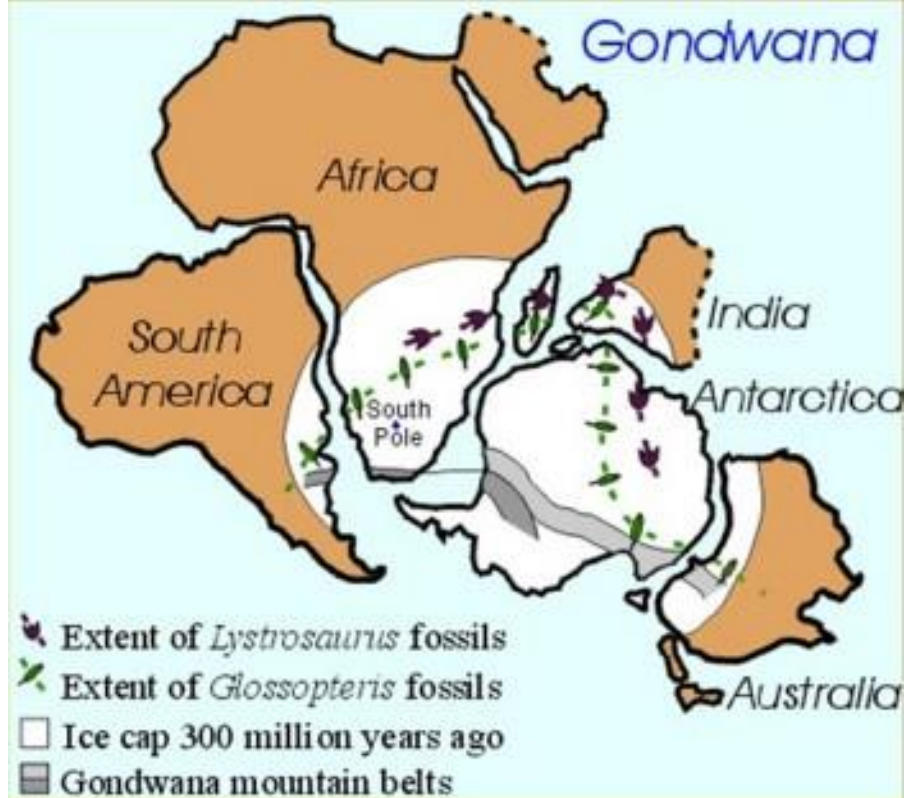
**115 Ma
Late Aptian**



**46 Ma
Middle Eocene**



0 Ma



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Afrika

Indien

Süd-Amerika

Australien

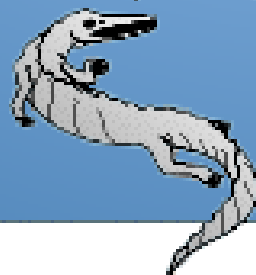
Antarktika



Lystrosaurus,
ein Landreptil
aus der Trias,
hatte eine weite
Verbreitung



Cynognathus,
ein landlebendes
Säugetierähnliches
Reptil (Therapsida)
aus der Trias



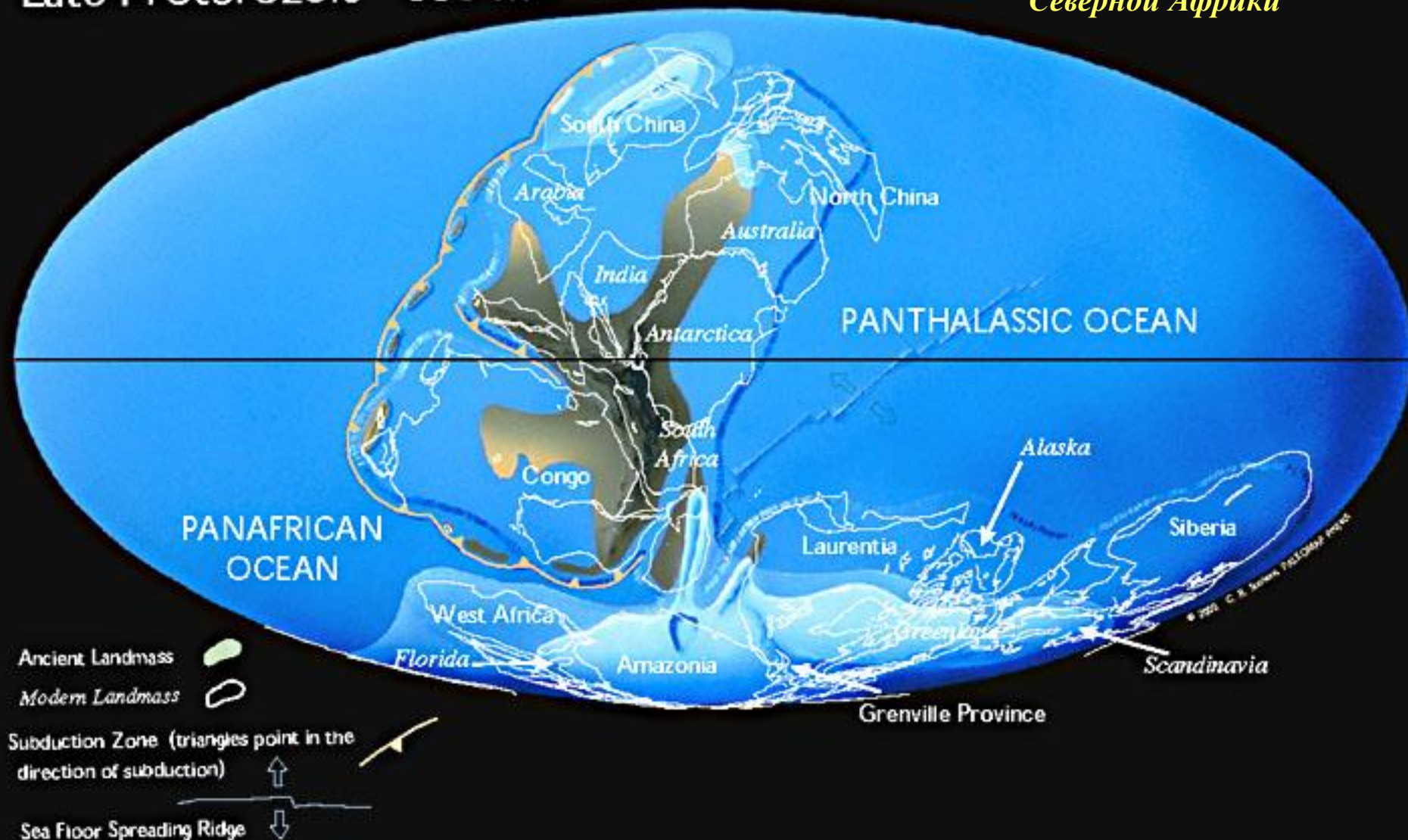
Mesosaurus,
ein süßwasserbe-
wohnendes Reptil
aus dem Perm



Fossilien des Farns
Glossopteris werden
auf allen früheren
Landmassen Gond-
wanas gefunden

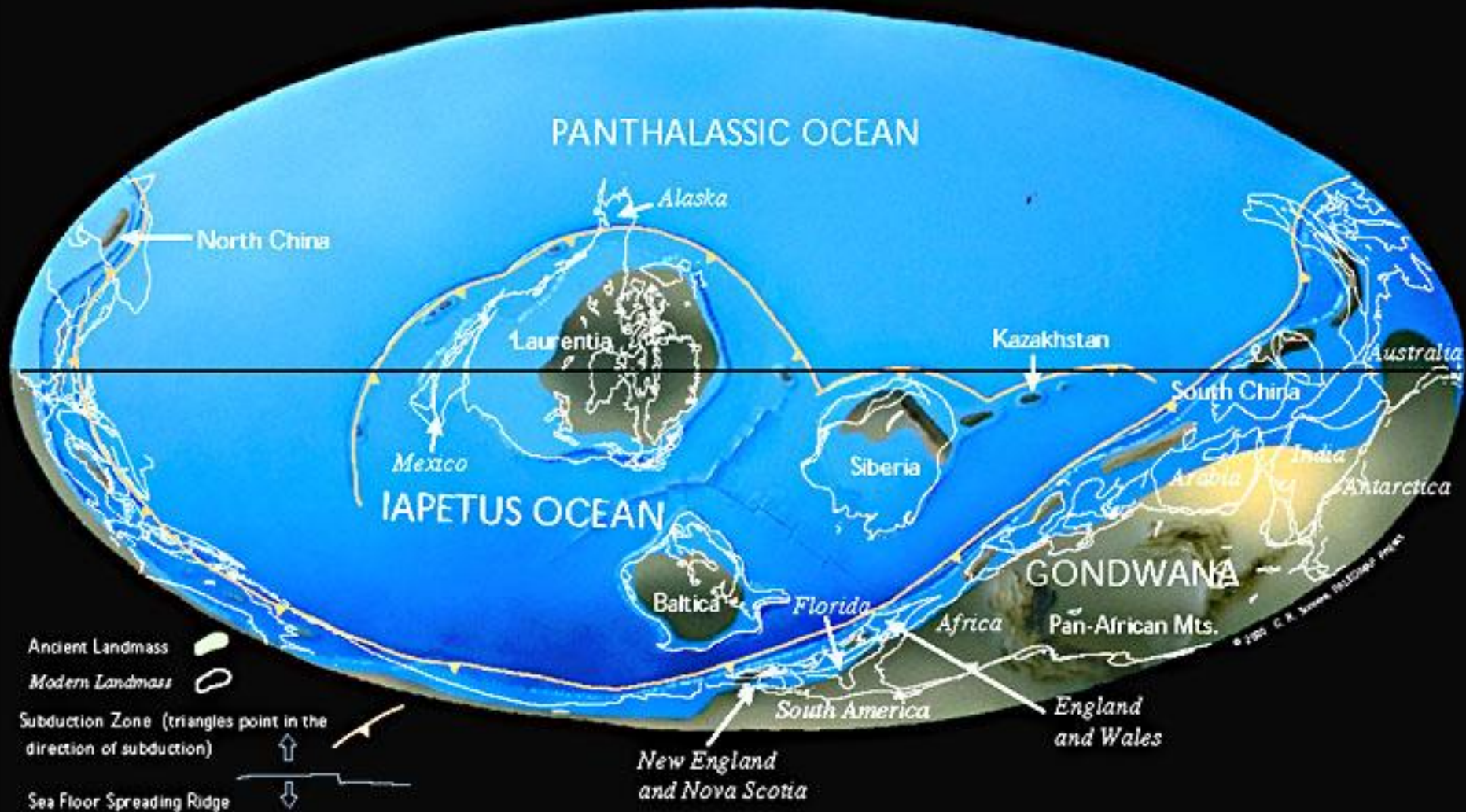
Late Proterozoic 650 Ma

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Late Cambrian 514 Ma

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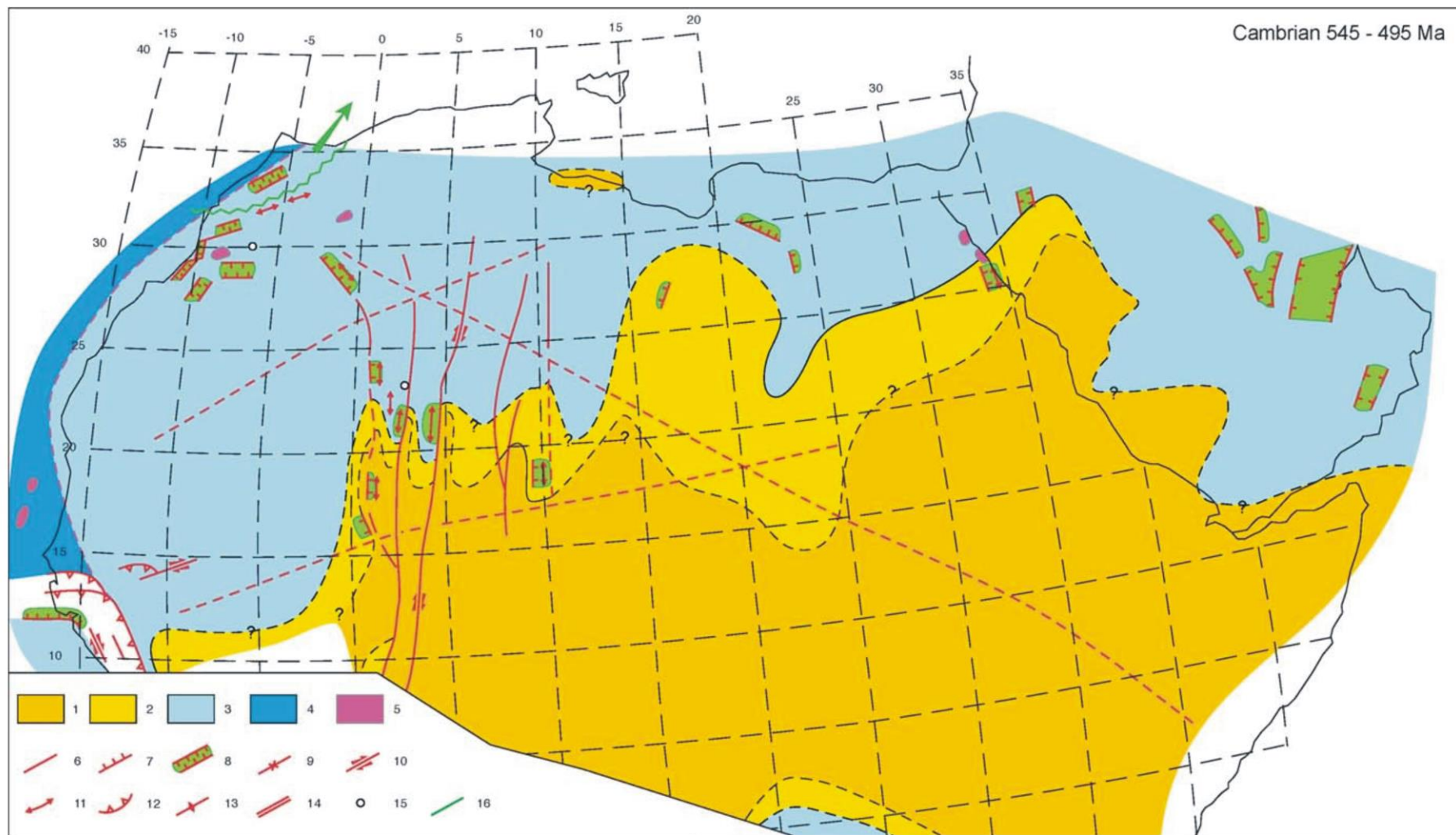
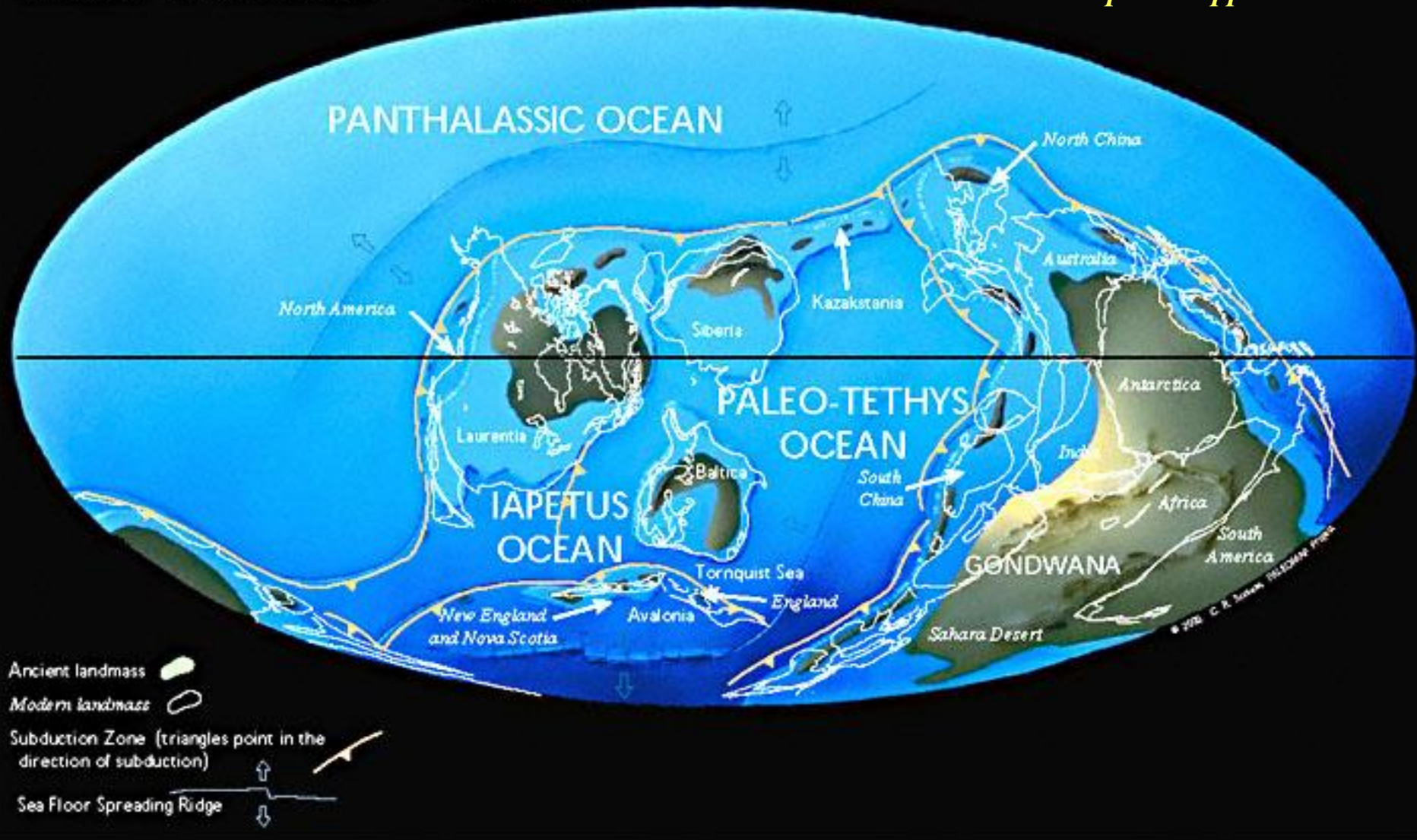


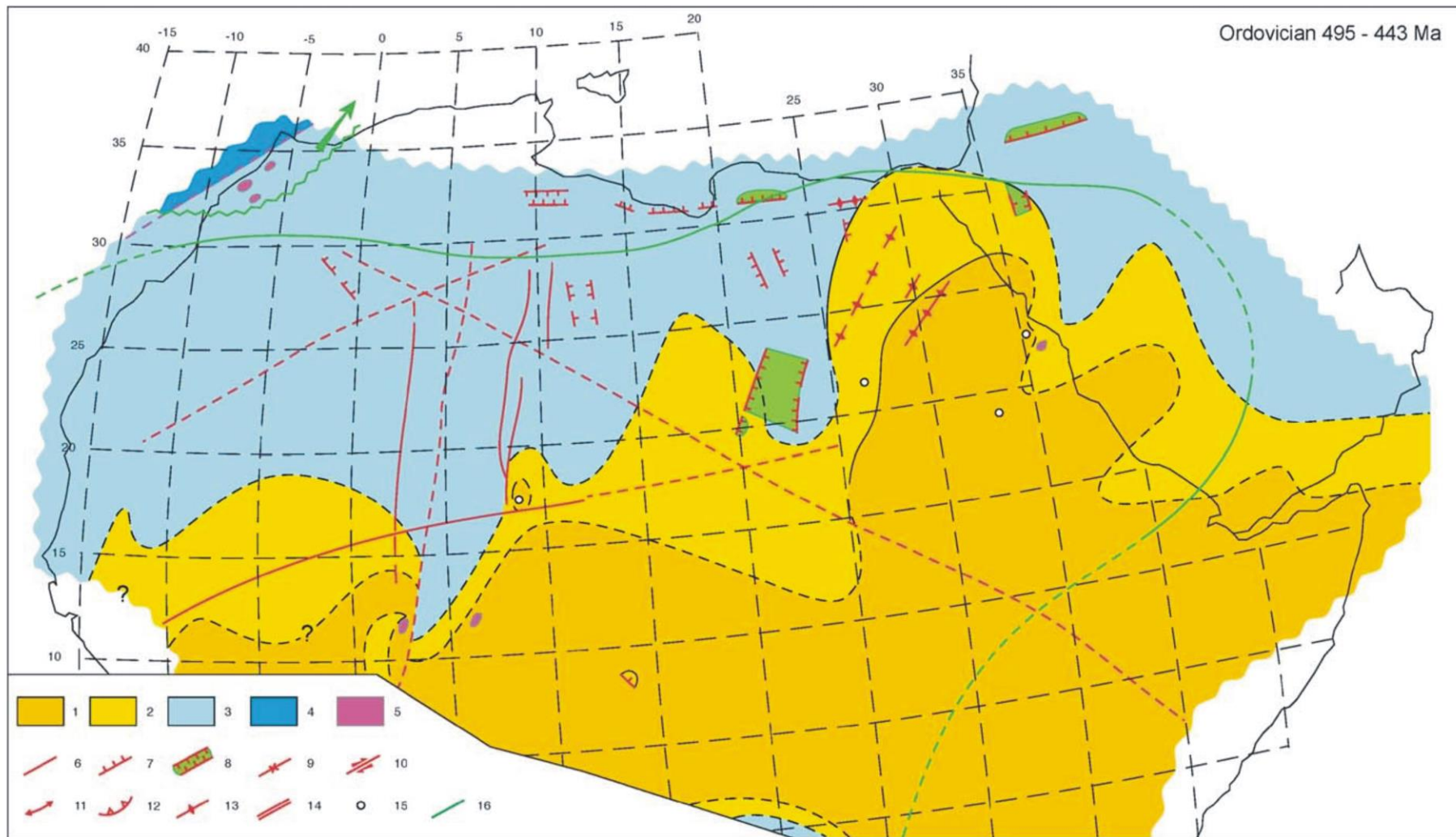
Fig. 6. Cambrian (545–495 Ma) paleogeological map. (1) Continental, exposed land; (2) continental basin; (3) platform; (4) slope and deep marine; (5) intrusive magmatism; (6) fault; (7) normal fault; (8) active rift or subsident basin; (9) depocenter axis; (10) strike-slip fault; (11) anticline axis; (12) thrust; (13) active high; (14) oceanic ridge; (15) annular alkaline complex; (16) dyke.

Middle Ordovician 458 Ma

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A

Fig. 11A. Ordovician (495–443 Ma) paleogeological map. Same legend as Fig. 6 The green line shows the maximum extent of the latest Ordovician ice sheet.
R. Guiraud et al. / Journal of African Earth Sciences 43 (2005) 83–143

Секвенции фанерозоя НГБ Северной Африки

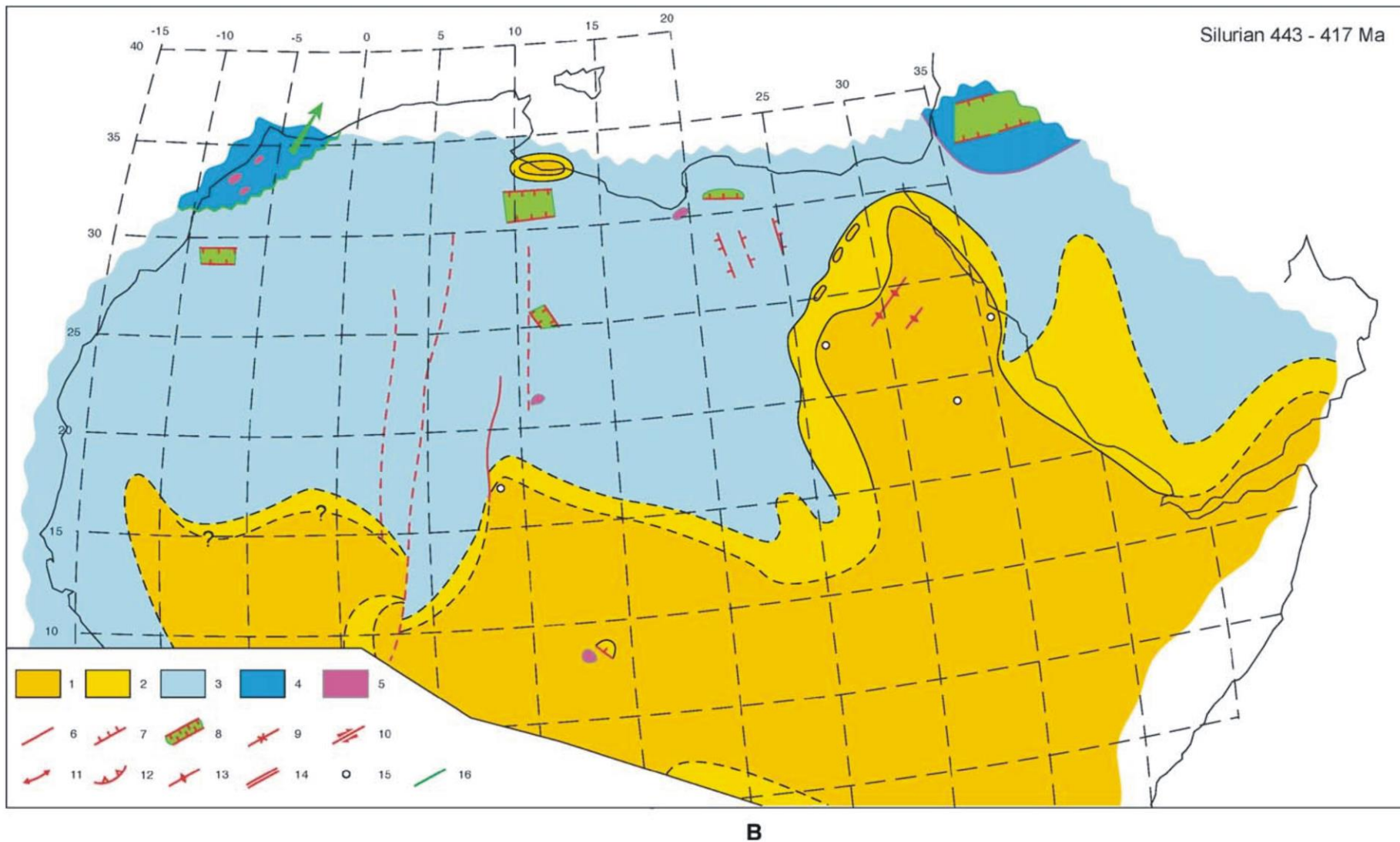
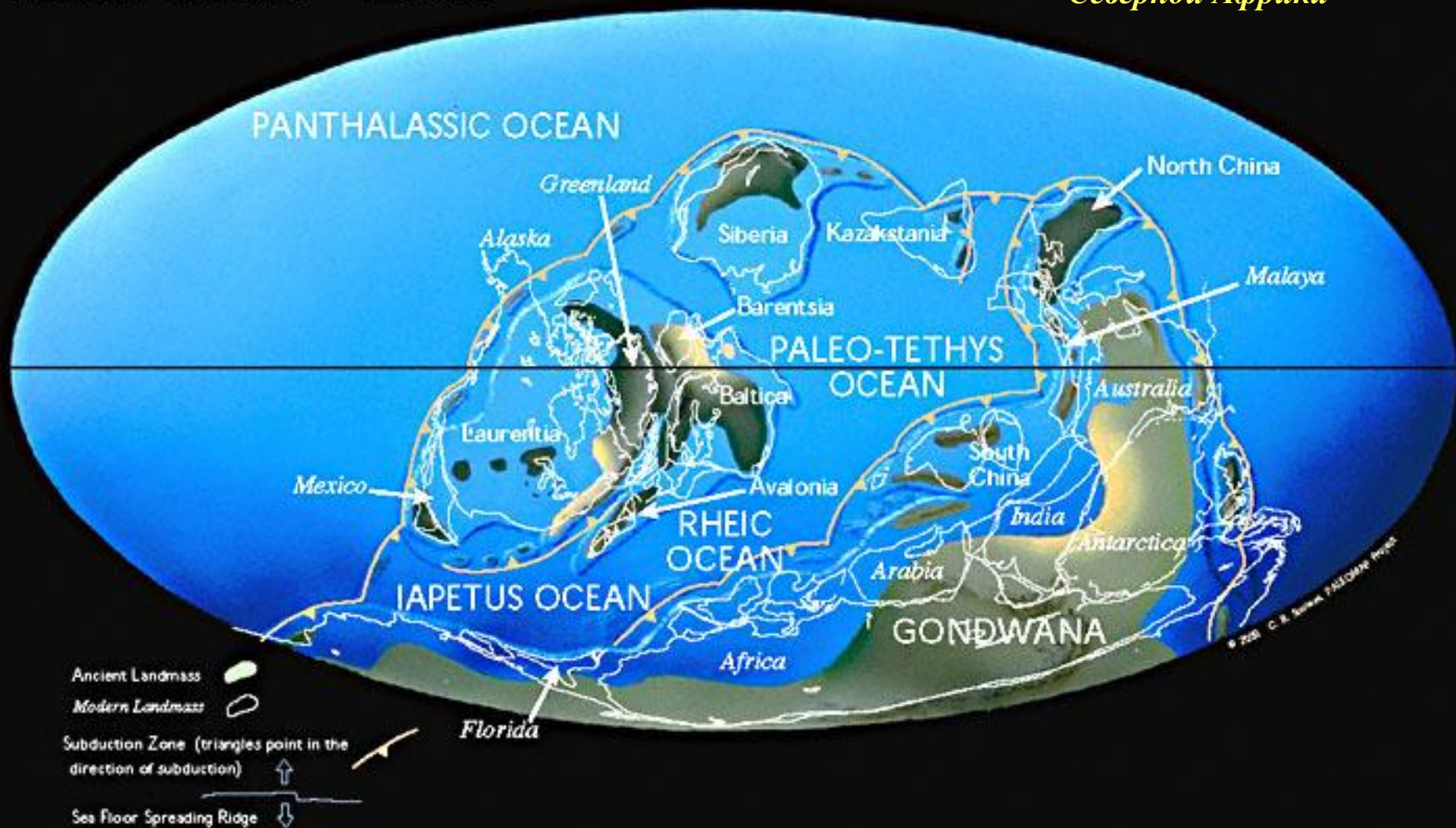


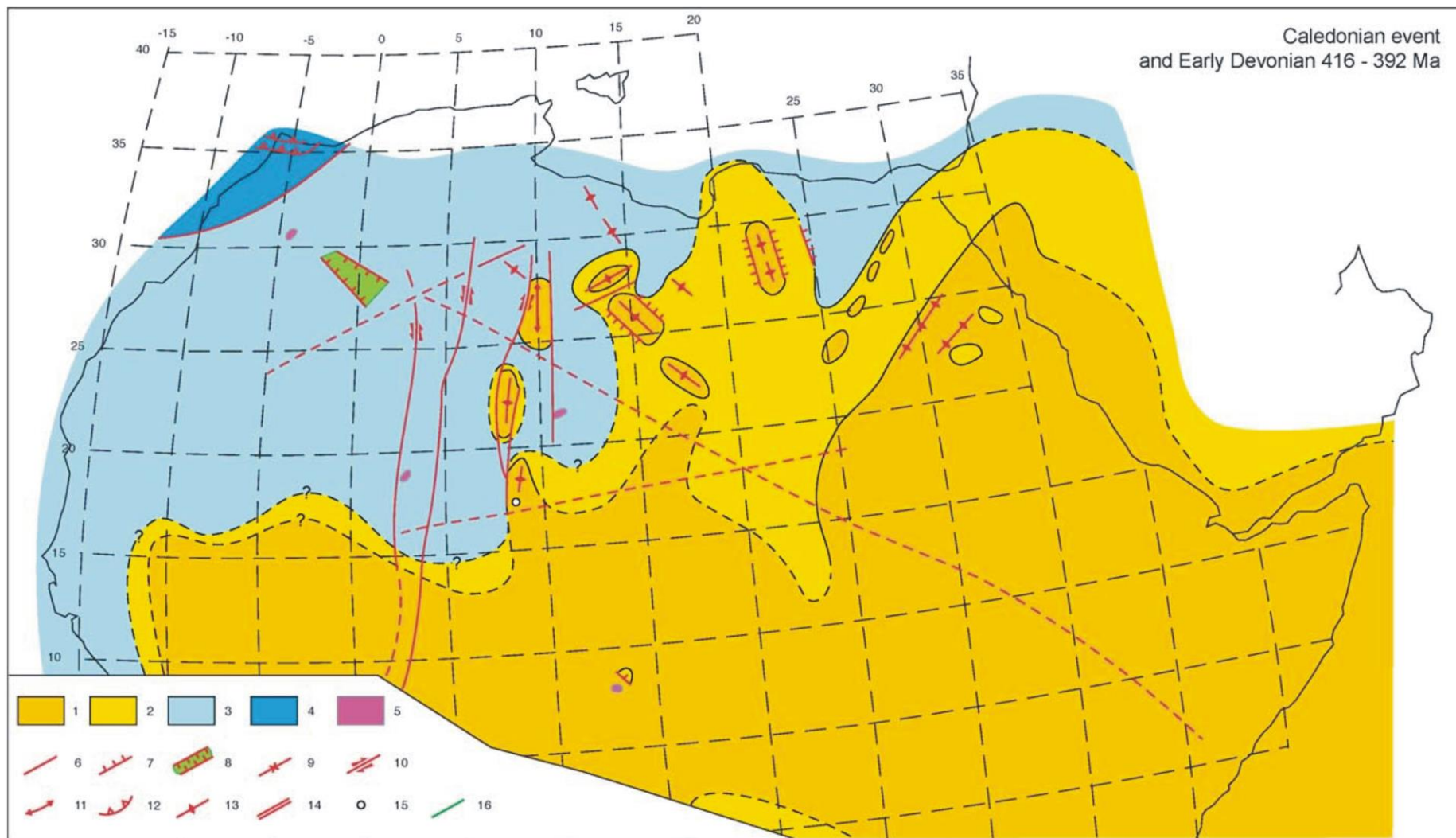
Fig. 11B. Silurian (443–417 Ma) paleogeological map. Same legend Fig. 6

Middle Silurian 425 Ma

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Секвенции фанерозоя НГБ Северной Африки



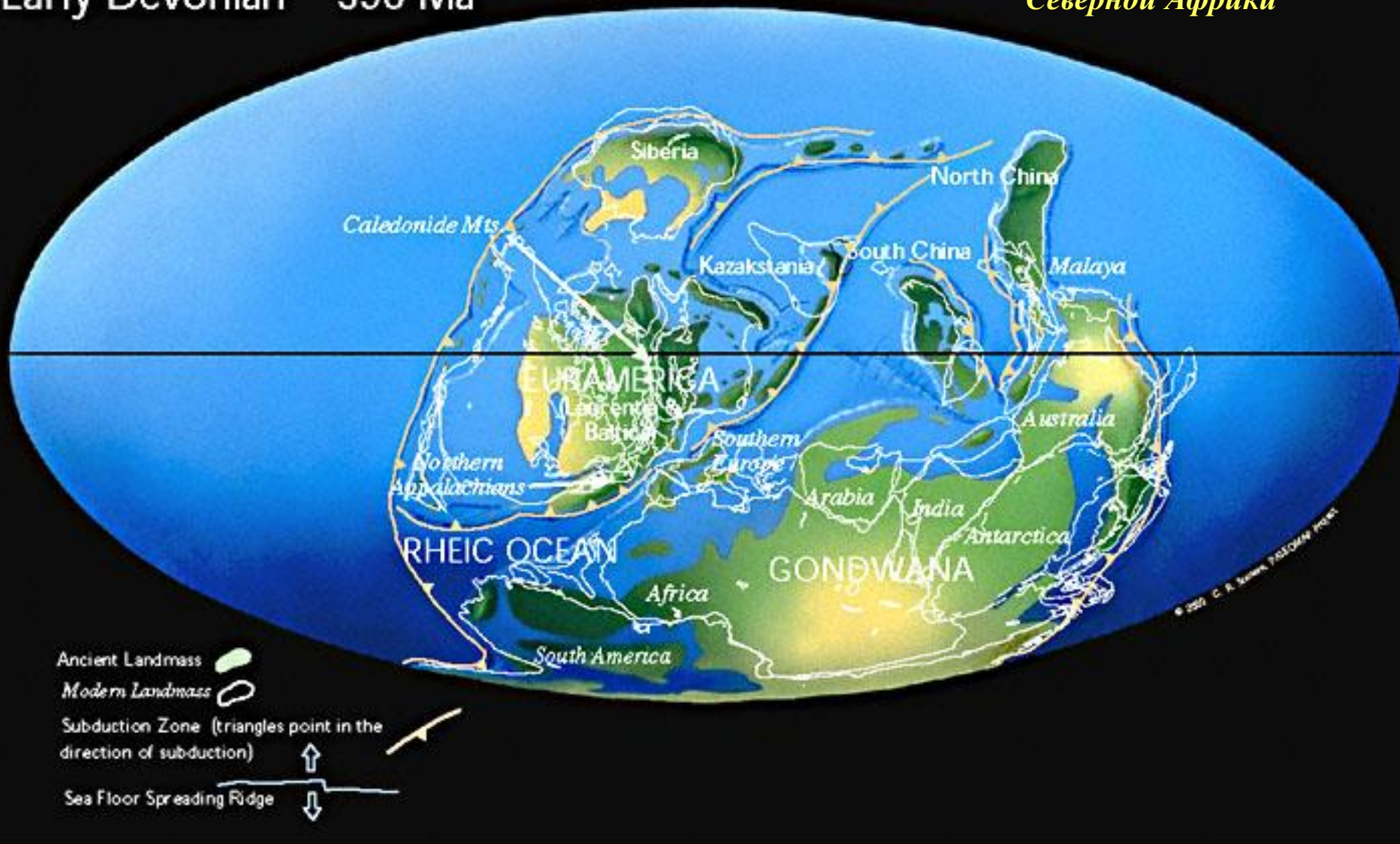
R. Guiraud et al. / Journal of African Earth Sciences 43 (2005) 83–143

A

Fig. 14A. Caledonian event and Early Devonian (416–392 Ma) paleogeological map

Early Devonian 390 Ma

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Секвенции фанерозоя НГБ Северной Африки

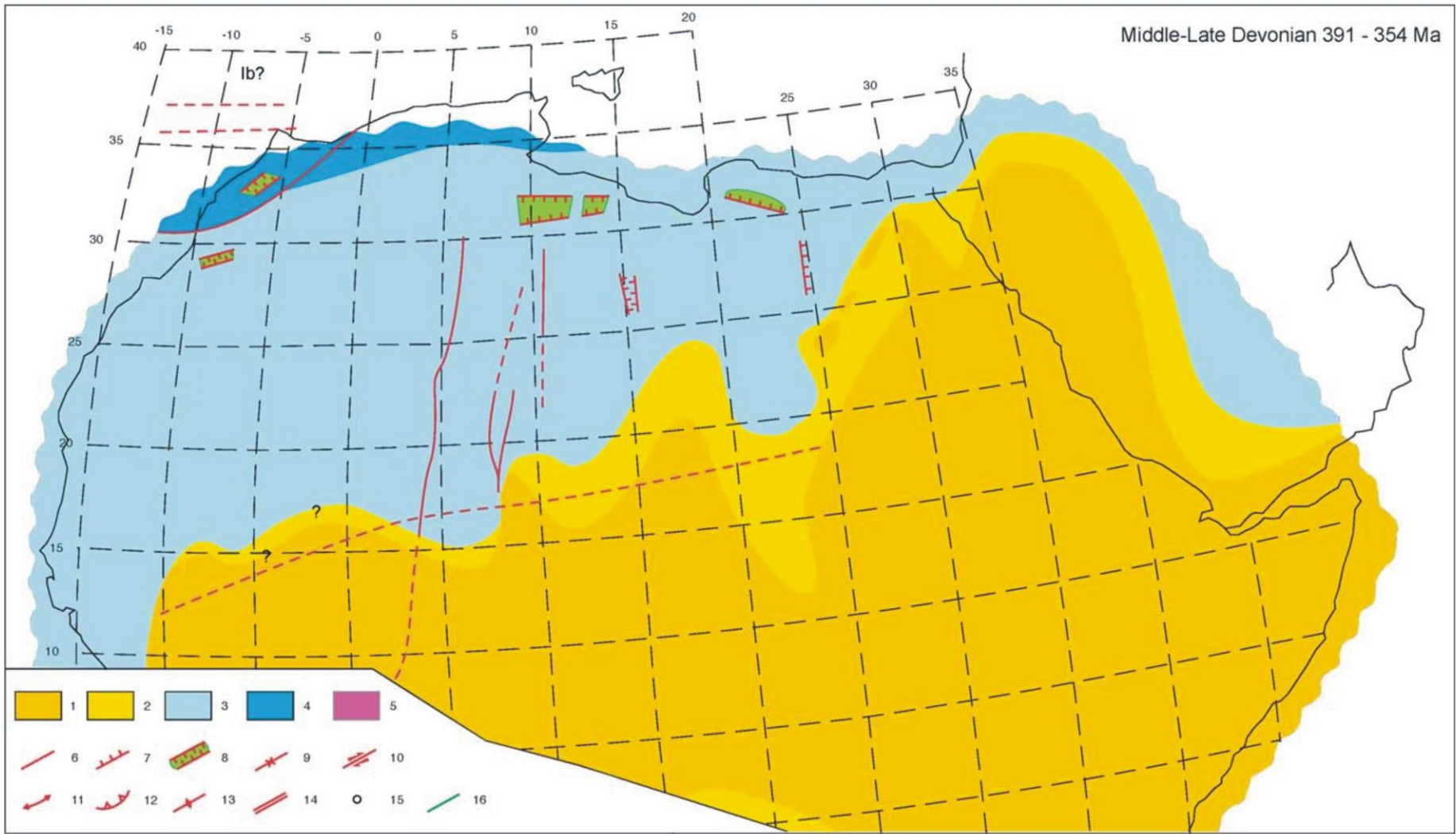
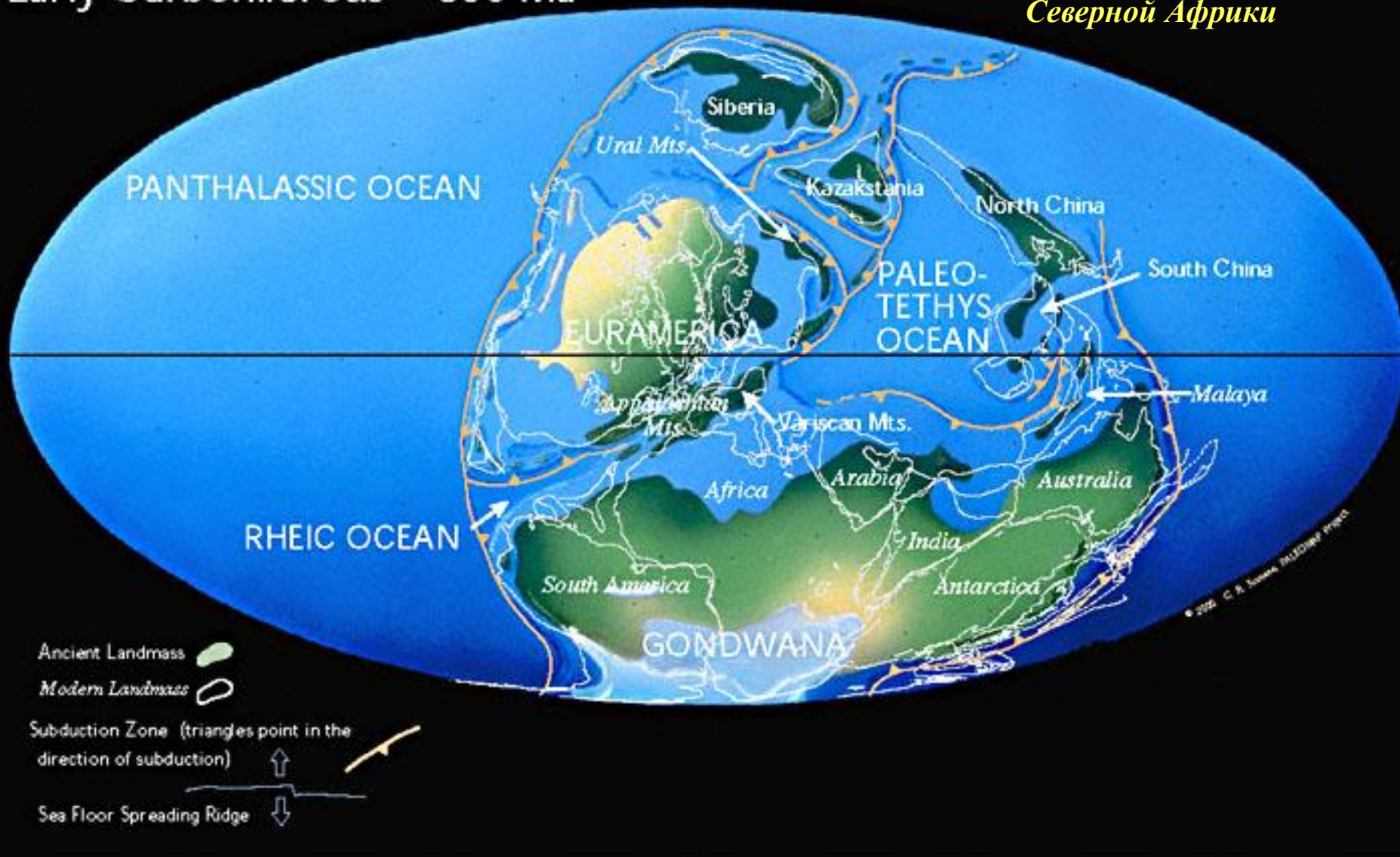
R. Guiraud et al. / Journal of African Earth Sciences 43 (2005) 83–143 **B**

Fig. 14B. Middle–Late Devonian (391–354 Ma) paleogeological map

Early Carboniferous 356 Ma

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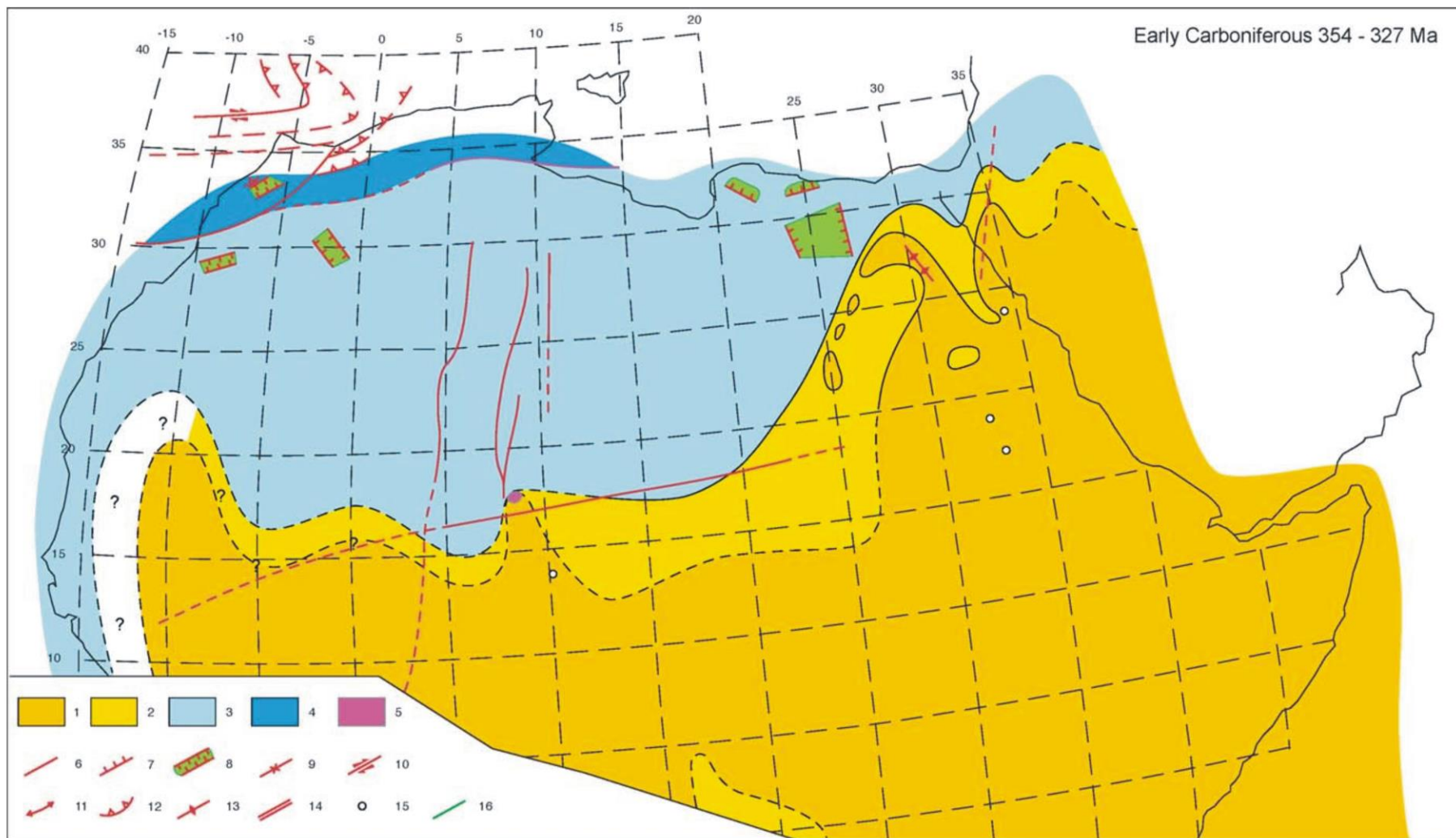


Fig. A. Early Carboniferous (354–327 Ma) paleogeological map

A

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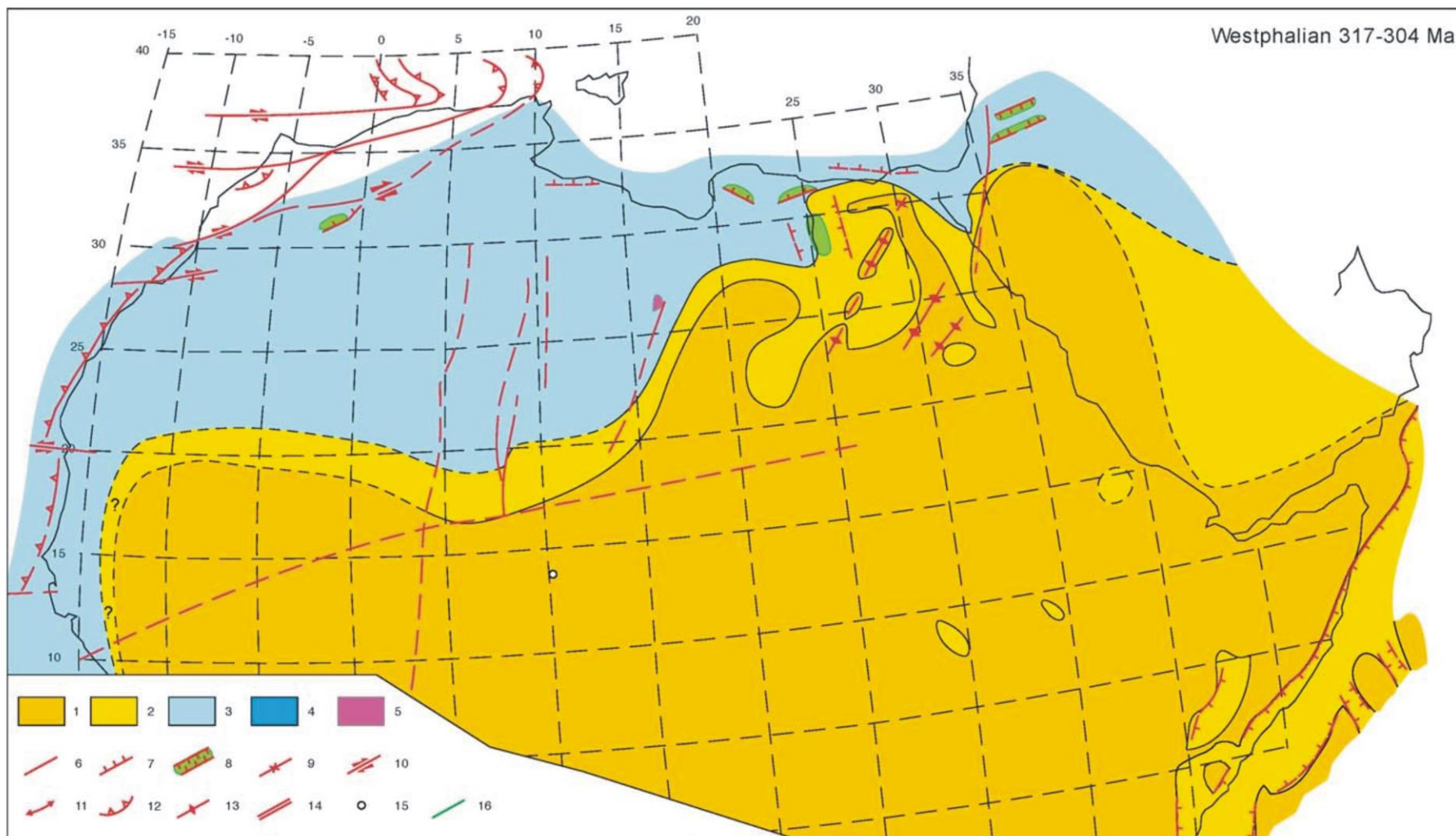
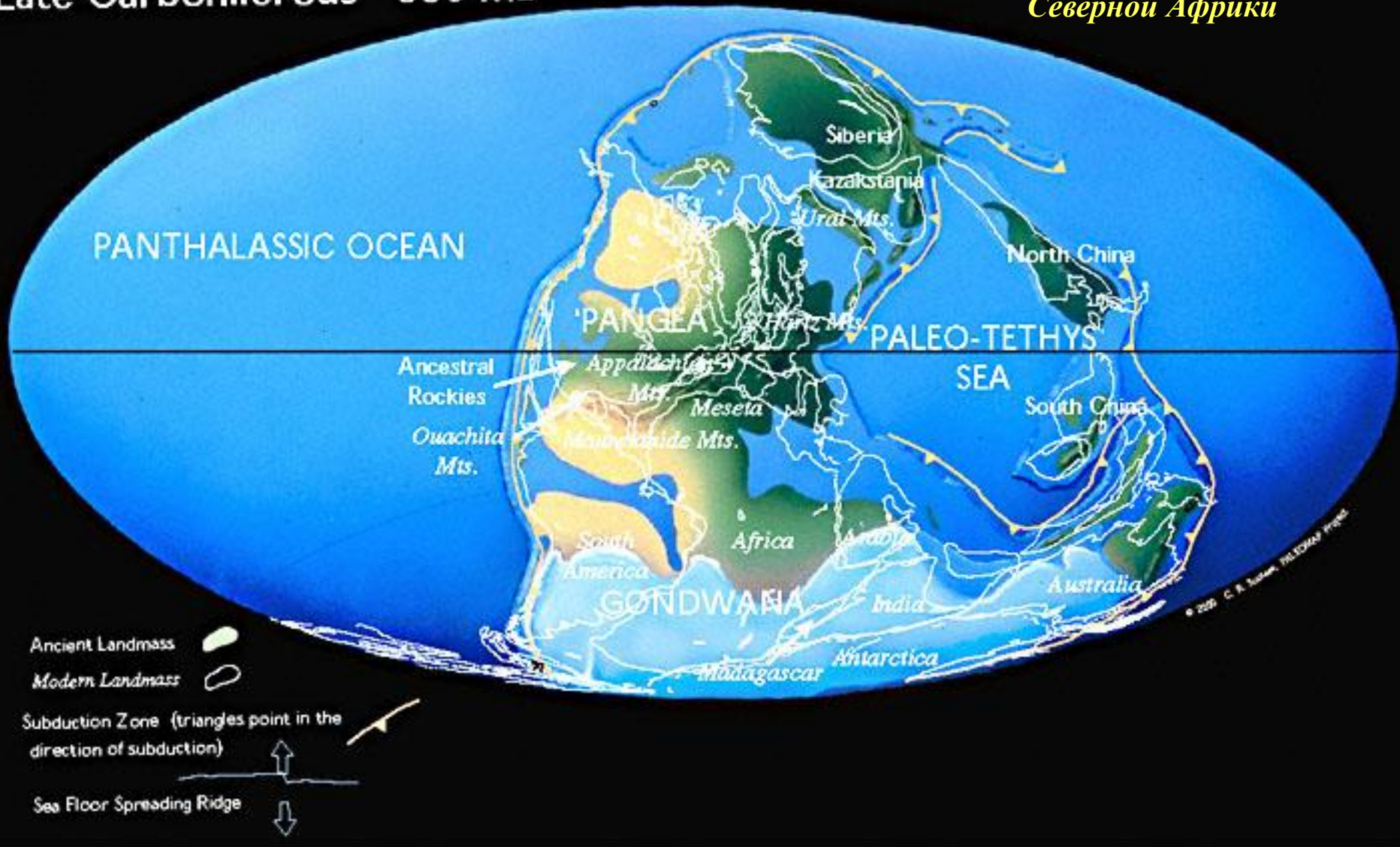


Fig. B. Westphalian (317–304 Ma) paleogeological map

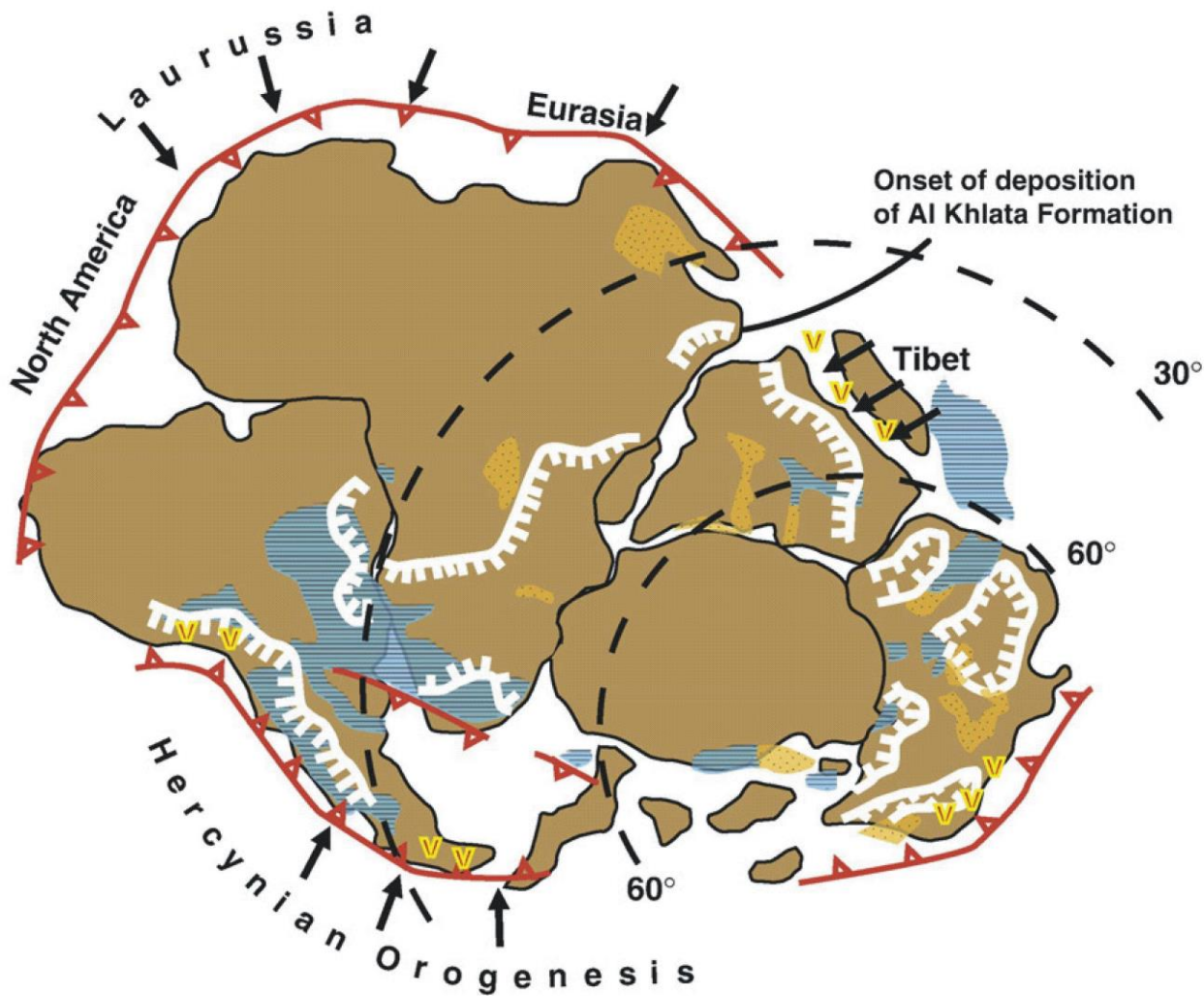
B

Late Carboniferous 306 Ma

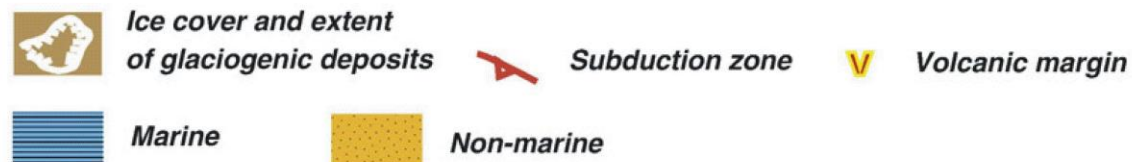
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D.P. Le Heron et al. / Earth-Science Reviews 93 (2009) 47–76



Palaeogeography of Gondwana during the Pennsylvanian. The initiation of Late Palaeozoic ice cover was broadly time transgressive, passing from modern day west (South America) to east (Australia) (Note that ice cover became established at mid palaeo-latitudes in Oman; ice sheets were absent further west in North Africa probably as a result of this latter area occupying low palaeo-latitudes and/or subdued relief.

Pennsylvanian

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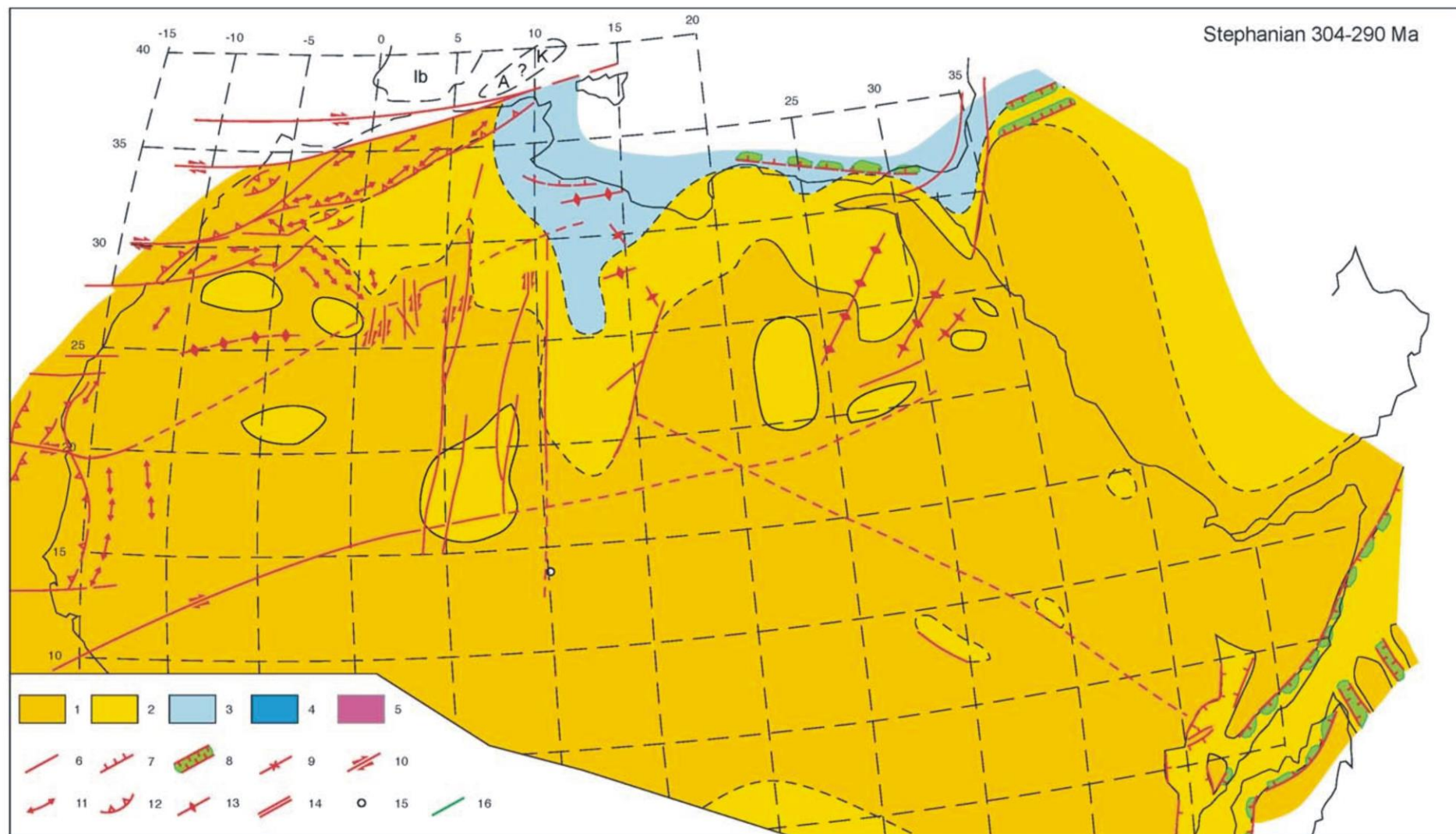


Fig. A. Stephanian (304–290 Ma) paleogeological map

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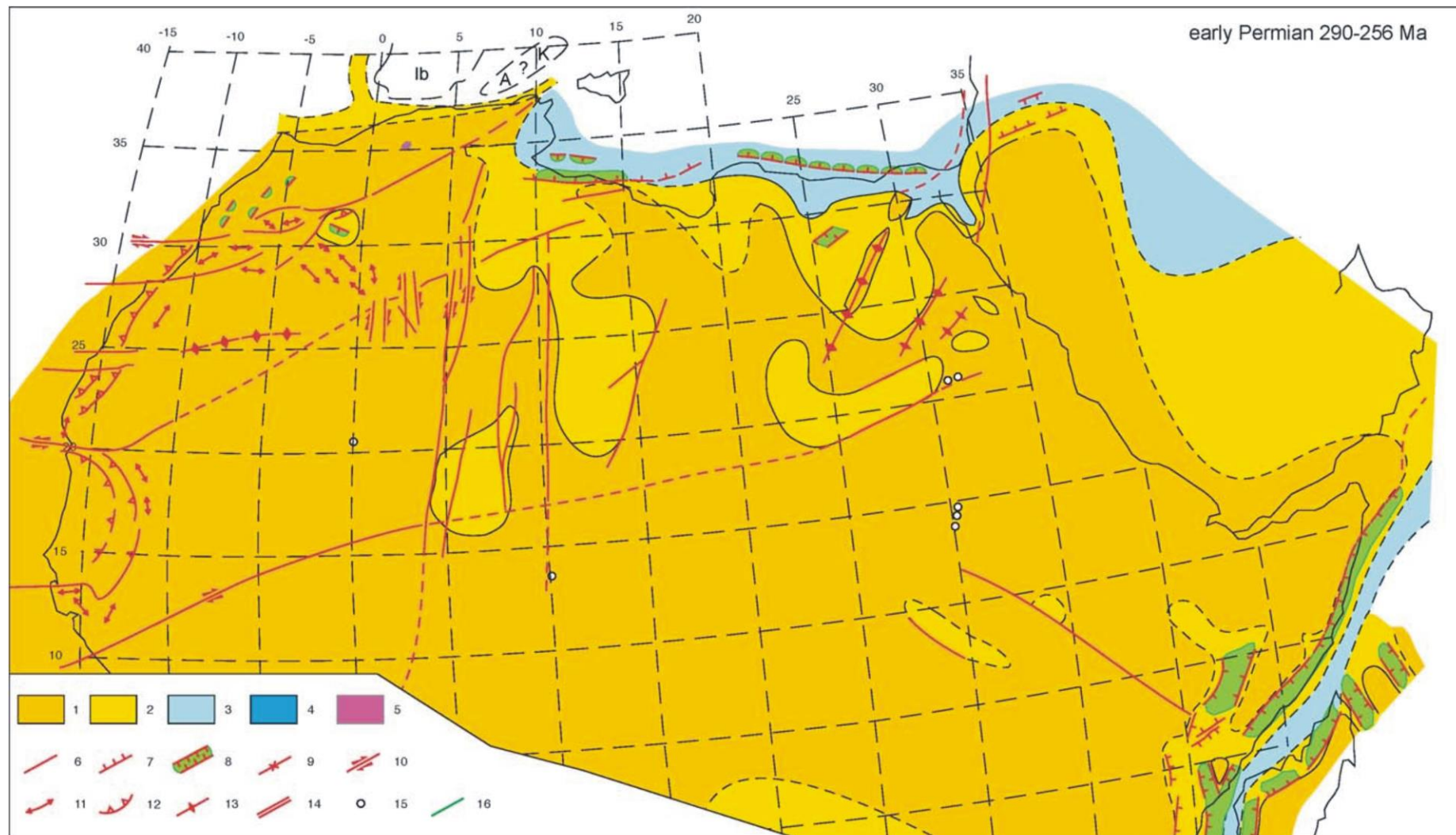


Fig. B. Early Permian (290–256 Ma) paleogeological map

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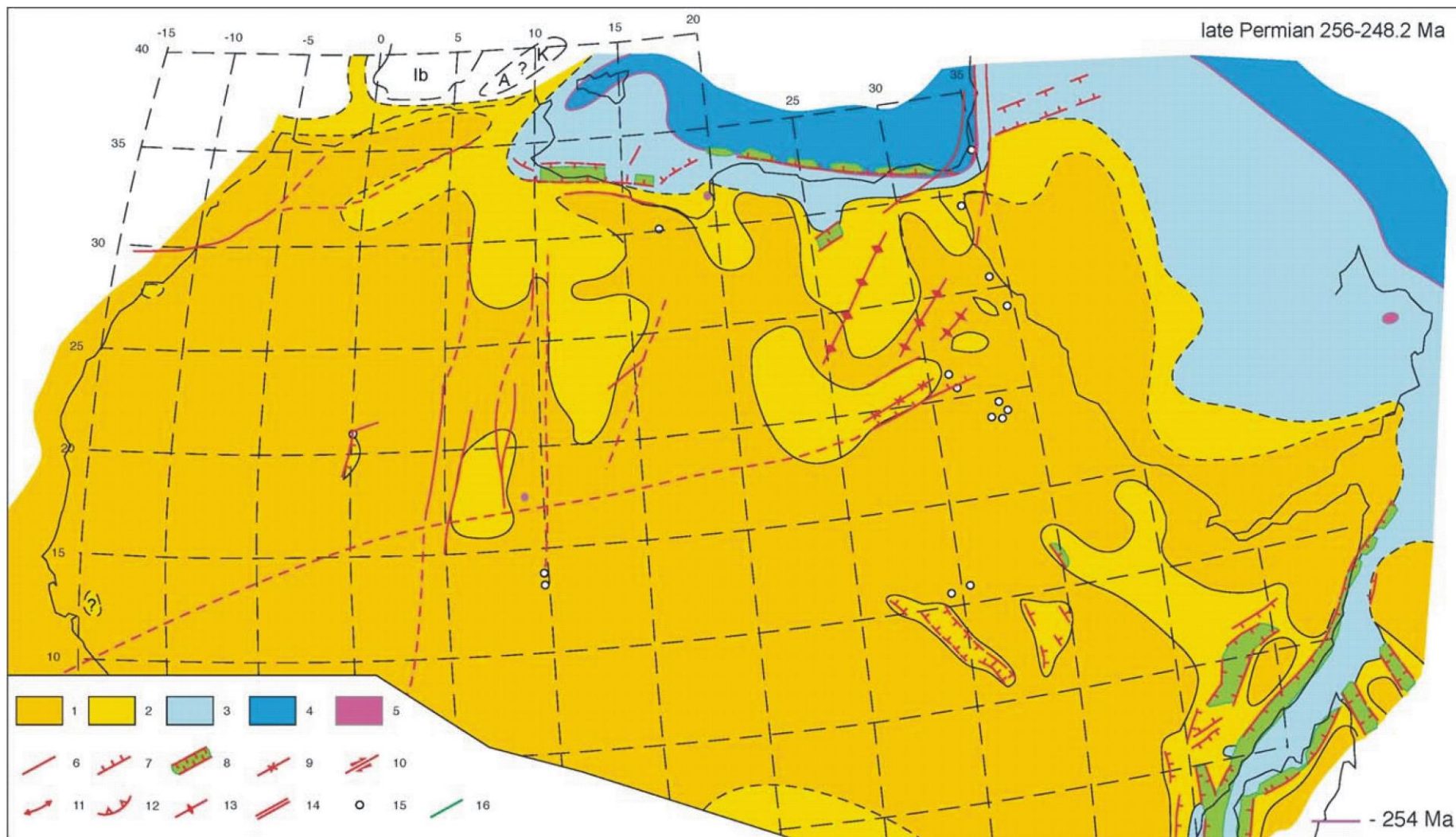
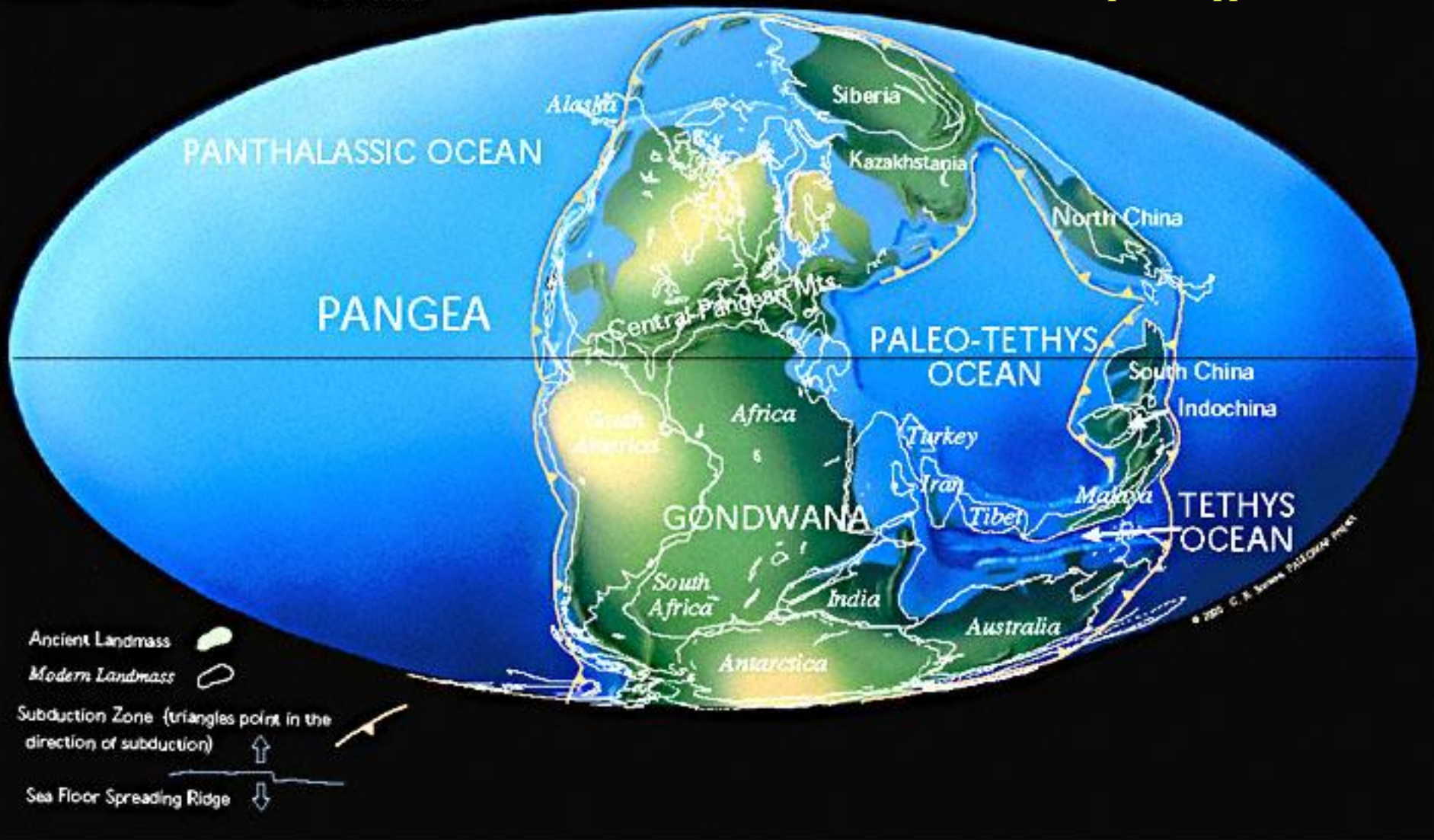


Fig . Late Permian (256–248.2 Ma) paleogeological map

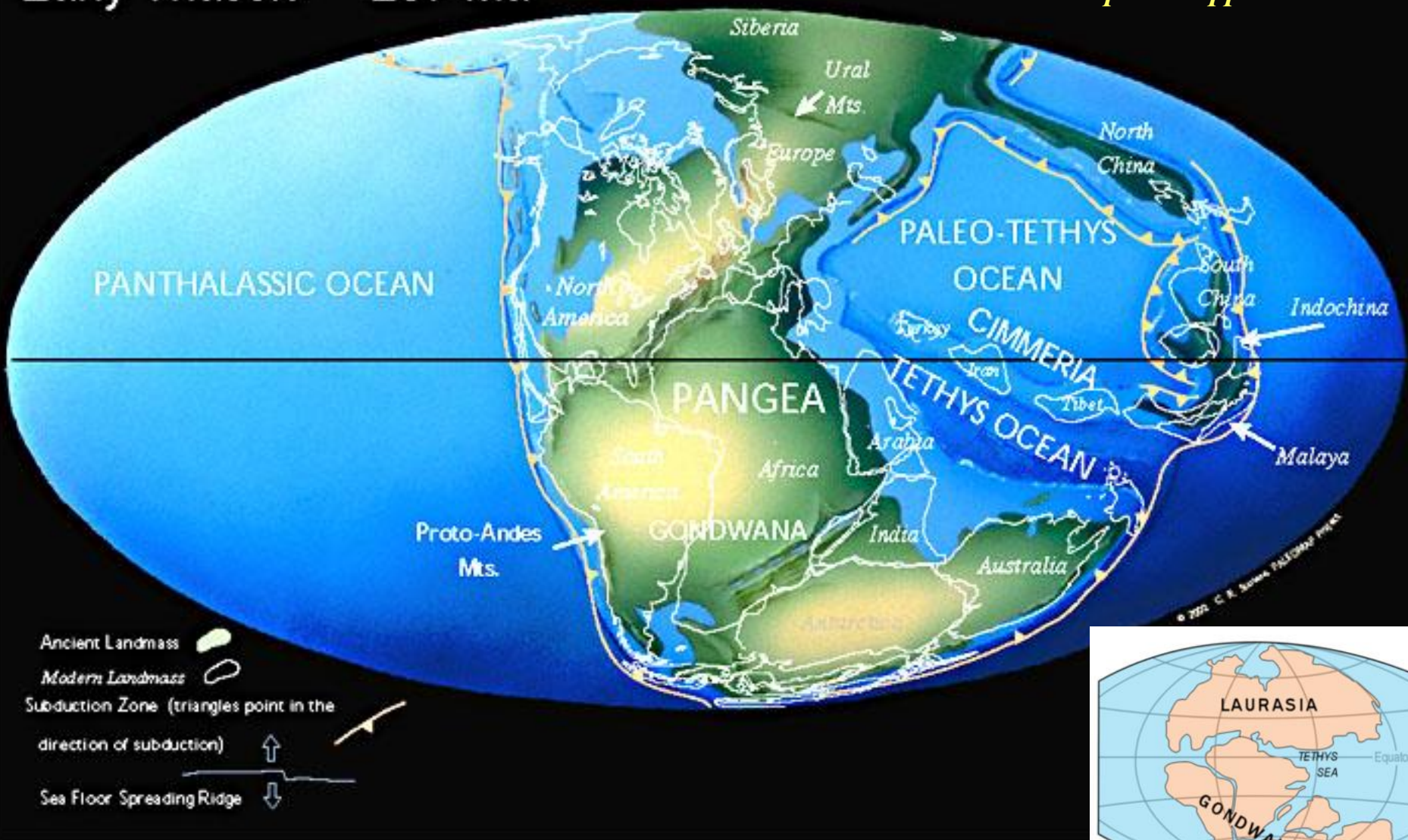
Late Permian 255 Ma

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Северной Африки

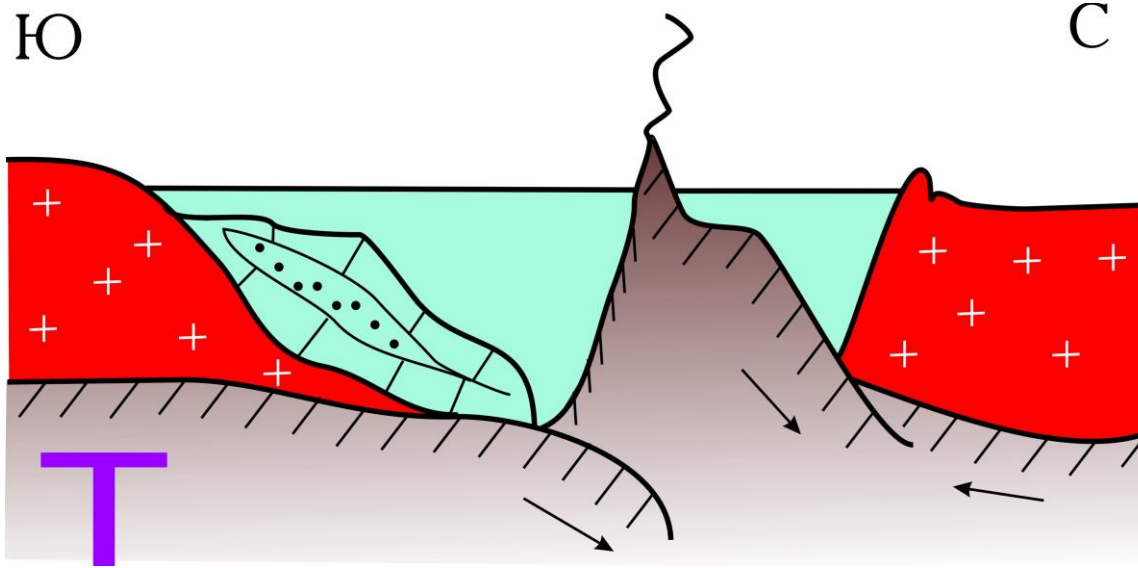


Early Triassic 237 Ma

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Северной Африки



TRIASSIC
200 million years ago



ЮВ часть Средиземноморского пояса (Тибетско-Индокитайская)

В триасе – продолжение и завершение РЗ геосинклинального развития. Существование ЮВ остатка Палеотетиса в виде залива от впадины Тихого океана. Накопление органогенно-карбонатных, кремнисто-сланцевых и песчаных толщ. В основном, это отложения миогеосинклинального типа южной массивной окраины Палеотетиса. Местами среди этих осадочных толщ встречаются пачки эффузивов преимущественно среднего (андезитового состава). Островодужная обстановка в сокращающемся реликте Палеотетиса.

В конце Т – окончательное закрытие ЮВ окончания Палеотетиса – Индосинийская (раннкиммерийская) фаза Мезозойской складчатости.

Юра и ранний мел – орогенный этап. Тибетско-Индокитайская область ранних мезозойских – воздымающаяся горно-складчатая область. Континентальные отложения (в К₁ красноцветные) отложения заполняют межгорные впадины.

Поздний мел – морская трансгрессия. Распространение толщ рудистовых известняков. Квазиплатформенный этап.

Секвенции фанерозоя НГБ Северной Африки

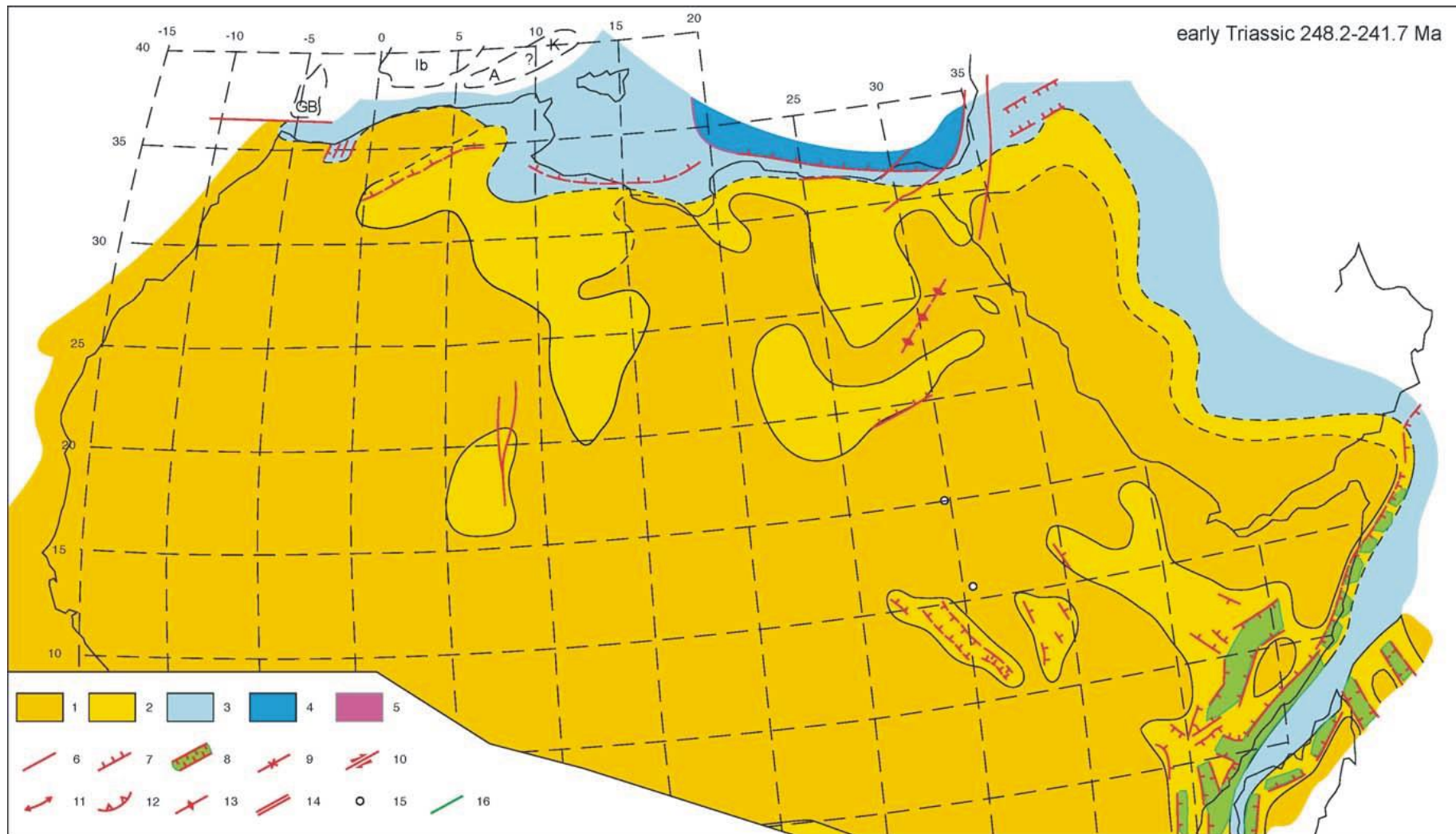


Fig. Early Triassic (248.2–241.7 Ma) paleogeological map

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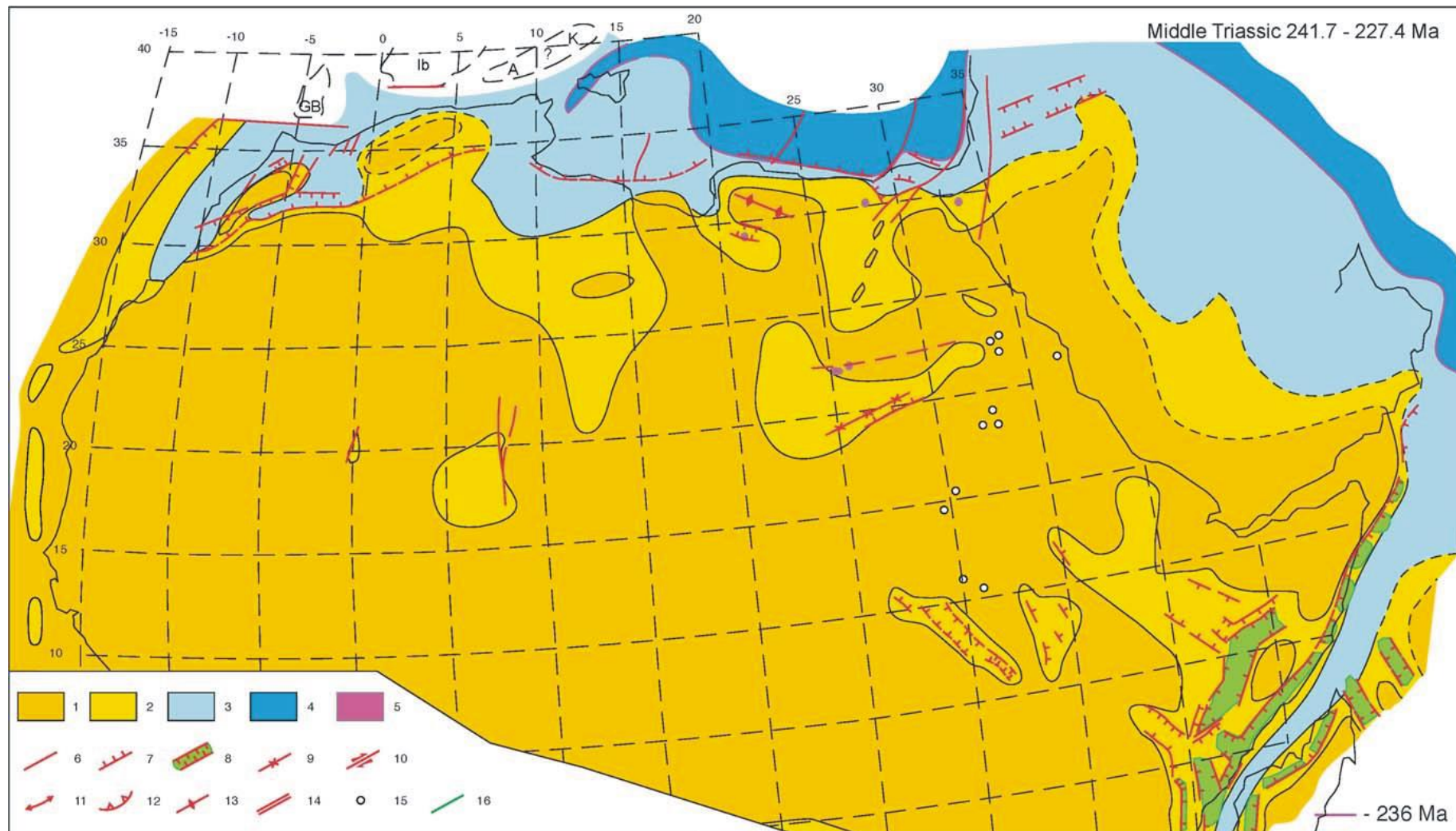


Fig. Middle Triassic (241.7–227.4 Ma) paleogeological map

B

Секвенции фанерозоя НГБ Северной Африки

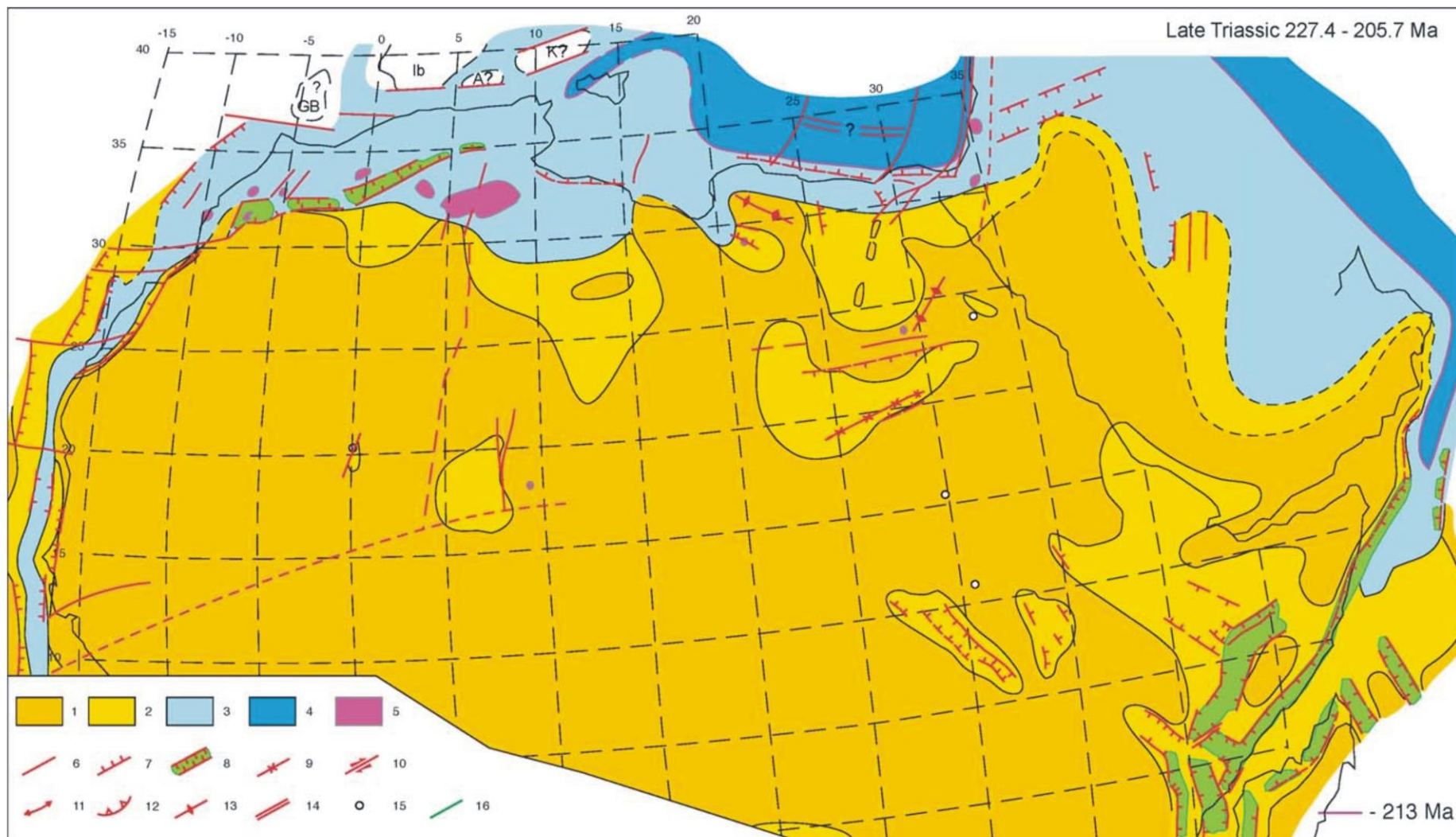
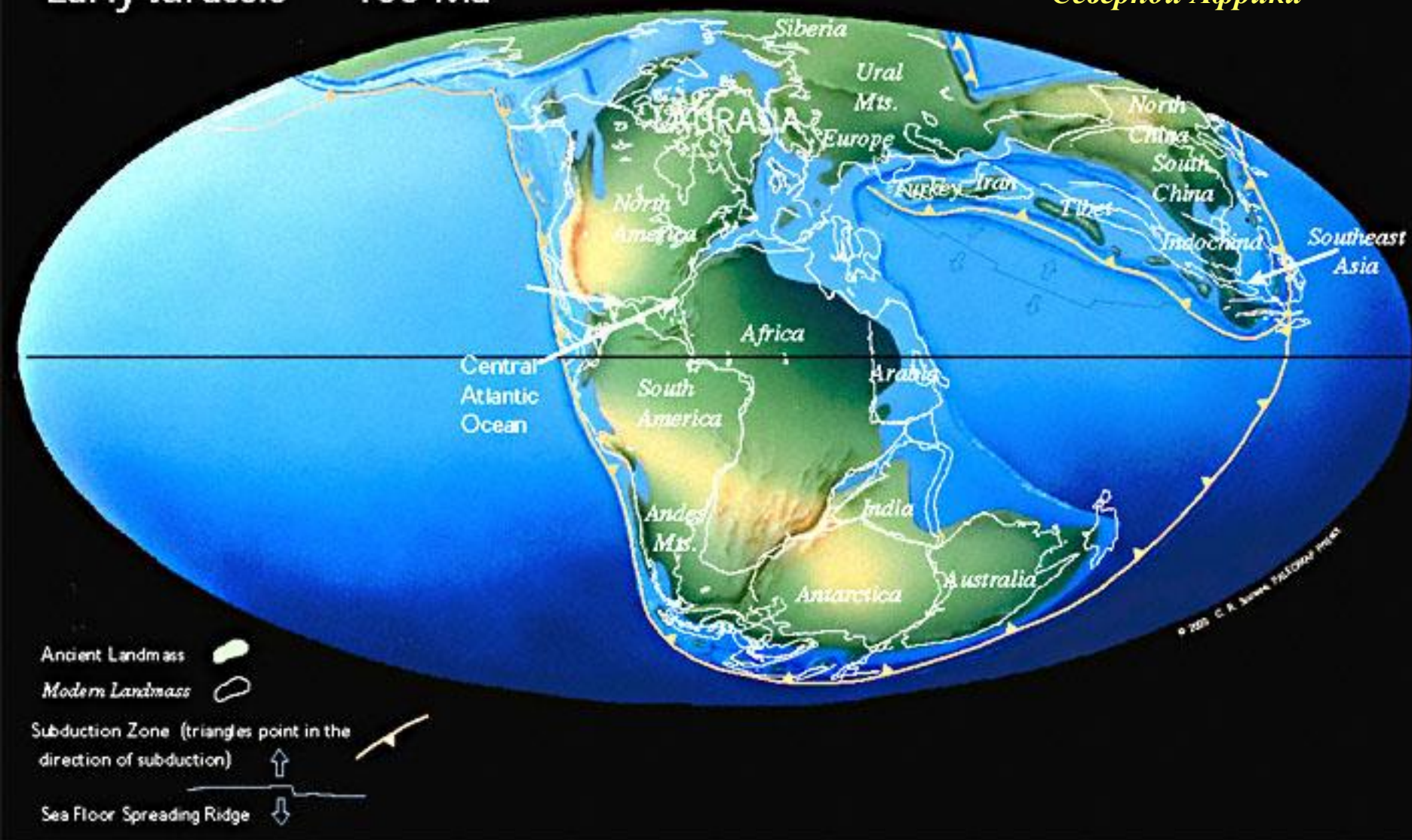


Fig. Late Triassic (227.4–205.7 Ma) paleogeological map

Early Jurassic 195 Ma

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Северной Африки*



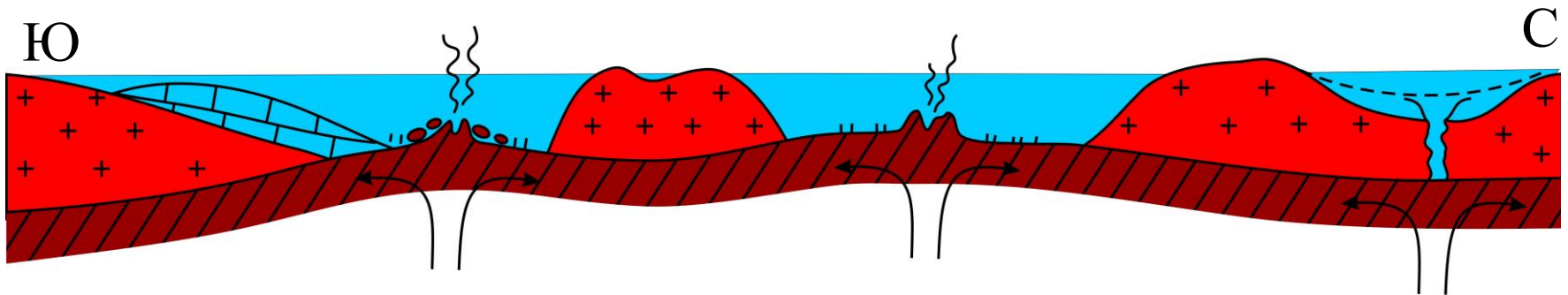
Основная часть Средиземноморского пояса

T – образование протяжённого мелководно-морского бассейна на теле Пангея-II, разделившего (палеогеографически) континенты Лавразия и Гондвана.

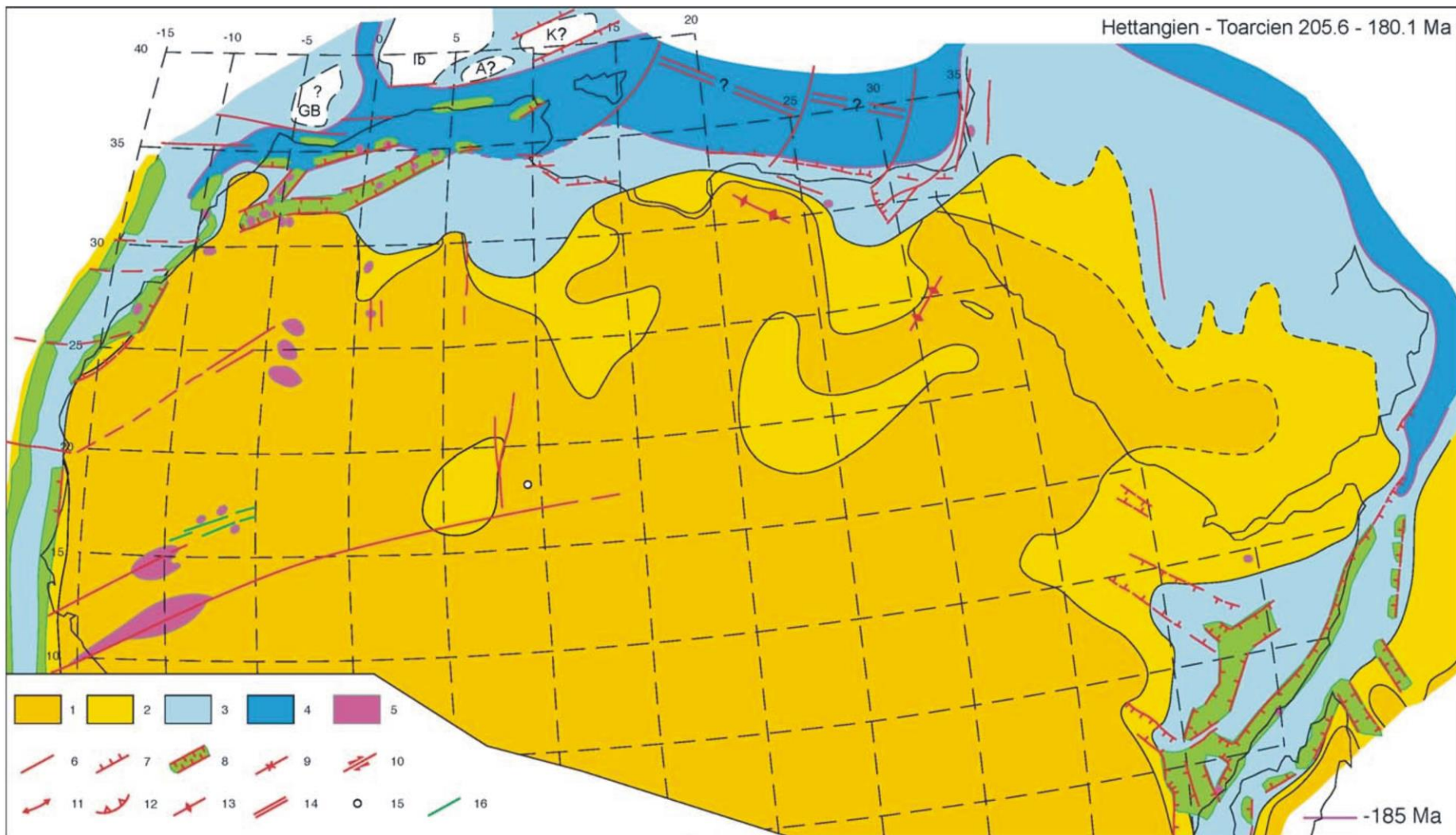
Накопление мелководно-морских толщ органогенных известняков однородной фацией на всём протяжении с З на В. Местами – лагунные песчаники, гипсы, доломиты.

J – возрождение на всем протяжении Средиземноморского пояса геосинклинального режима развития, каждый продолжался далее весь *MZ* и *Pg*. Эвгеосинклинальная зона – накопление глинистых сланцев, кремнистых пород, пелагических известняков с покровами подушечных базальтов, подстилаемых габбро и серпентинитами – т.е. полный комплекс пород офиолитовой ассоциации. Разрыв континентальной коры Пангеи II и образование океанического бассейна Тетис. Местами – 2 ветви Тетиса: Южная и Северная, разделённые микроконтинентами – срединными массивами Анатолийским и Иранским. На срединных массивах – локально распространенные маломощные мелководно-морские или лагунные отложения.

Две окраины Тетиса - пассивные. Широкая южная окраина – миогеосинклинальные прогибы с накоплением мелководно-морских карбонатных отложений (Ю. Альпы, Динариды, Тавр, Загрос). На северной окраине – зоны растяжения – система геосинклинальных прогибов (г. Крым - Б.Кавказ).



Секвенции фанерозоя НГБ Северной Африки



A A, Alboran; GB, Great Bank; Ib, Iberia; K, Kabylies.

Fig. Hettangian–Toarcian (205.7–180.1 Ma) paleogeological map

Секвенции фанерозоя НГБ Северной Африки

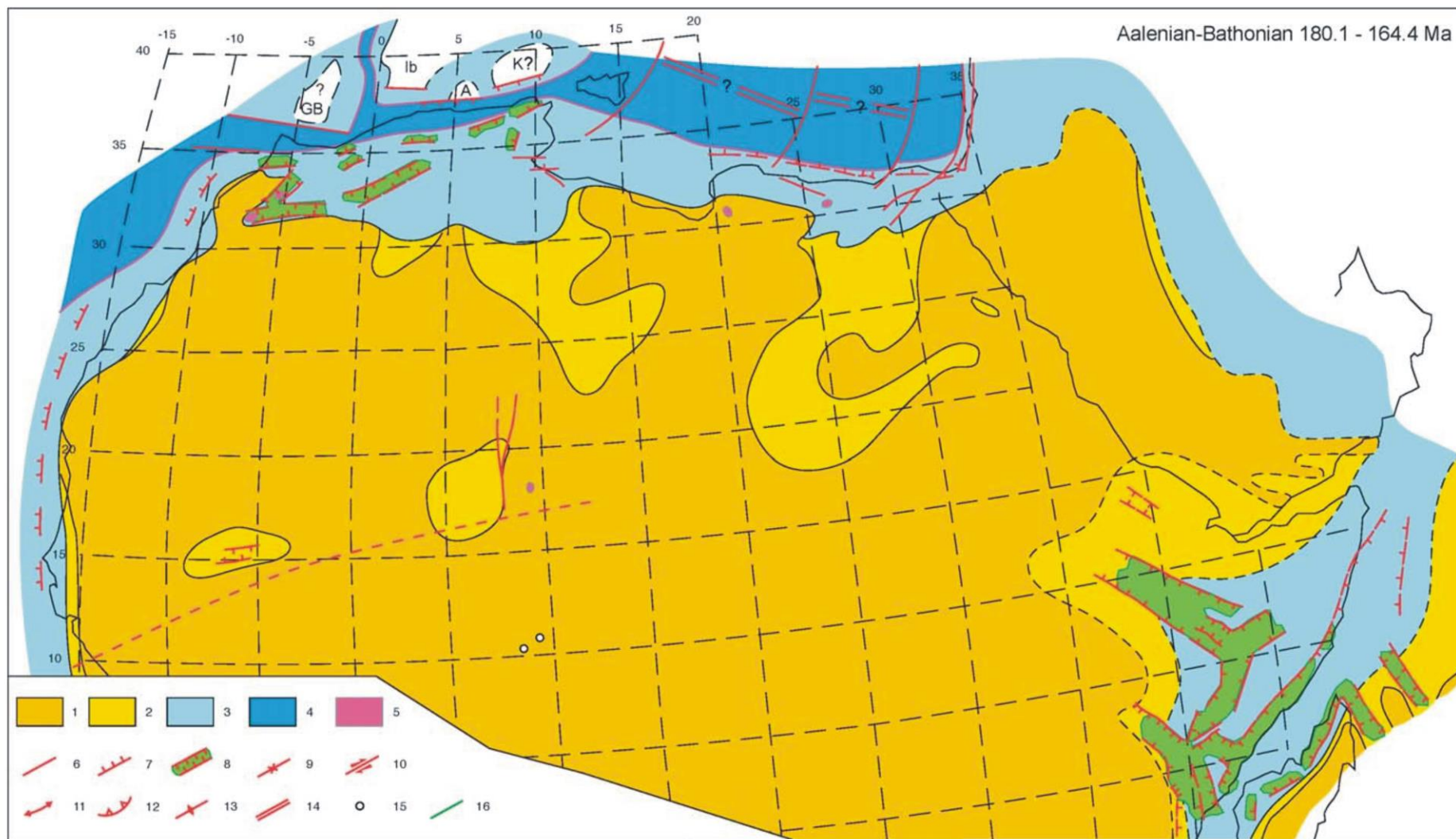


Fig. Aalenian-Bathonian (180–164.4 Ma) paleogeological map

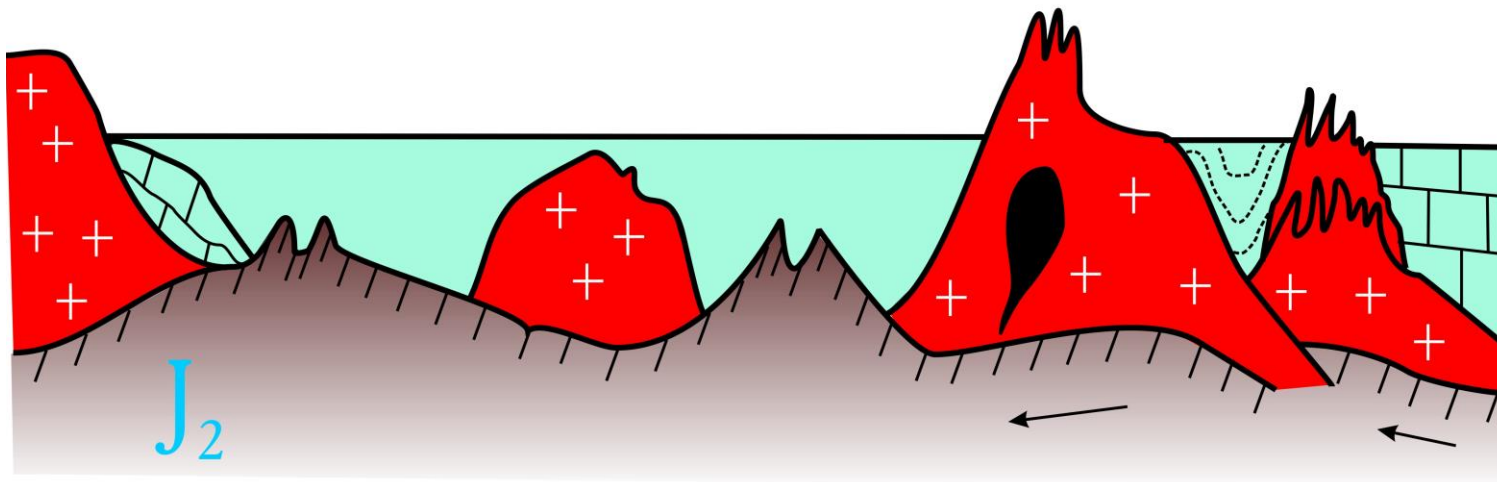
B

R. Guiraud et al. / Journal of African Earth Sciences 43 (2005) 83–143

Ю

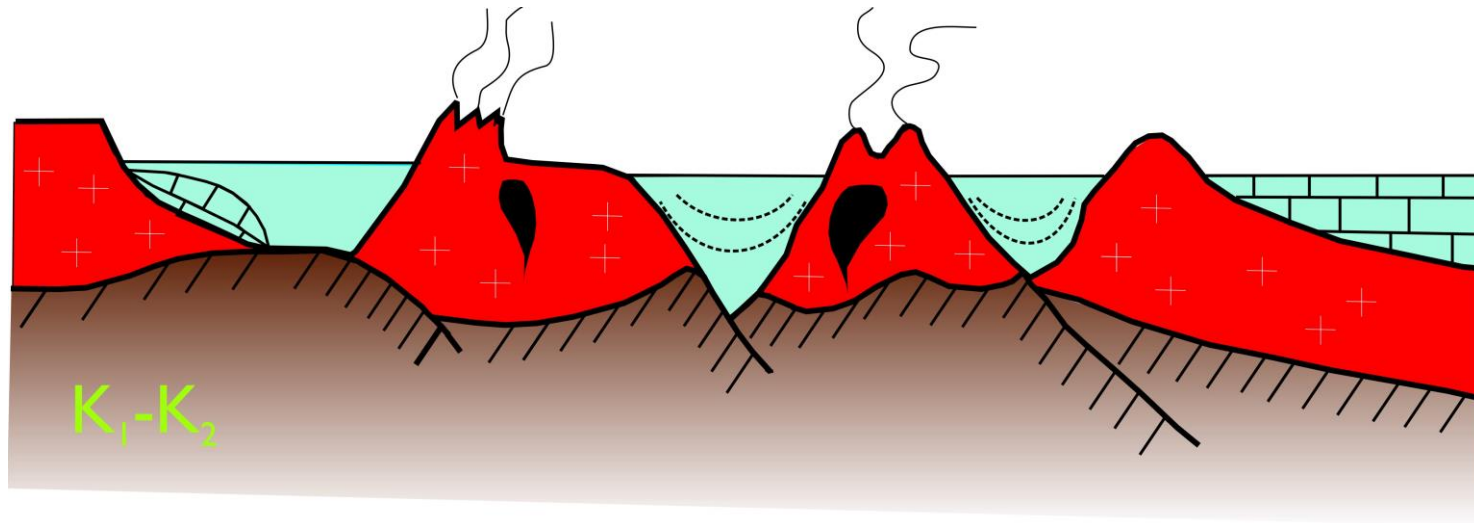
С

Большой Кавказ



На континентальной (утоненной) коре южной части Лавразии отчленение ещё одной полосы срединных массивов (Мизийский, Закавказский)
В начале J_2 – первые фазы сокращения северной ветви Тетиса. Северная окраина северной ветви становится активной

Ю



Субдукция океанической коры под Закавказский срединный массив. На нём – обширный вулкано-плутонический пояс. Сжатие и складчатость в прогибе Б. Кавказа. Центральное поднятие разделяет его на северную субплатформенную часть и зону южного склона – самый ранний флишевый прогиб.

В середине К (K₁/K₂) - новая фаза сокращения уже по всей ширине Тетиса.

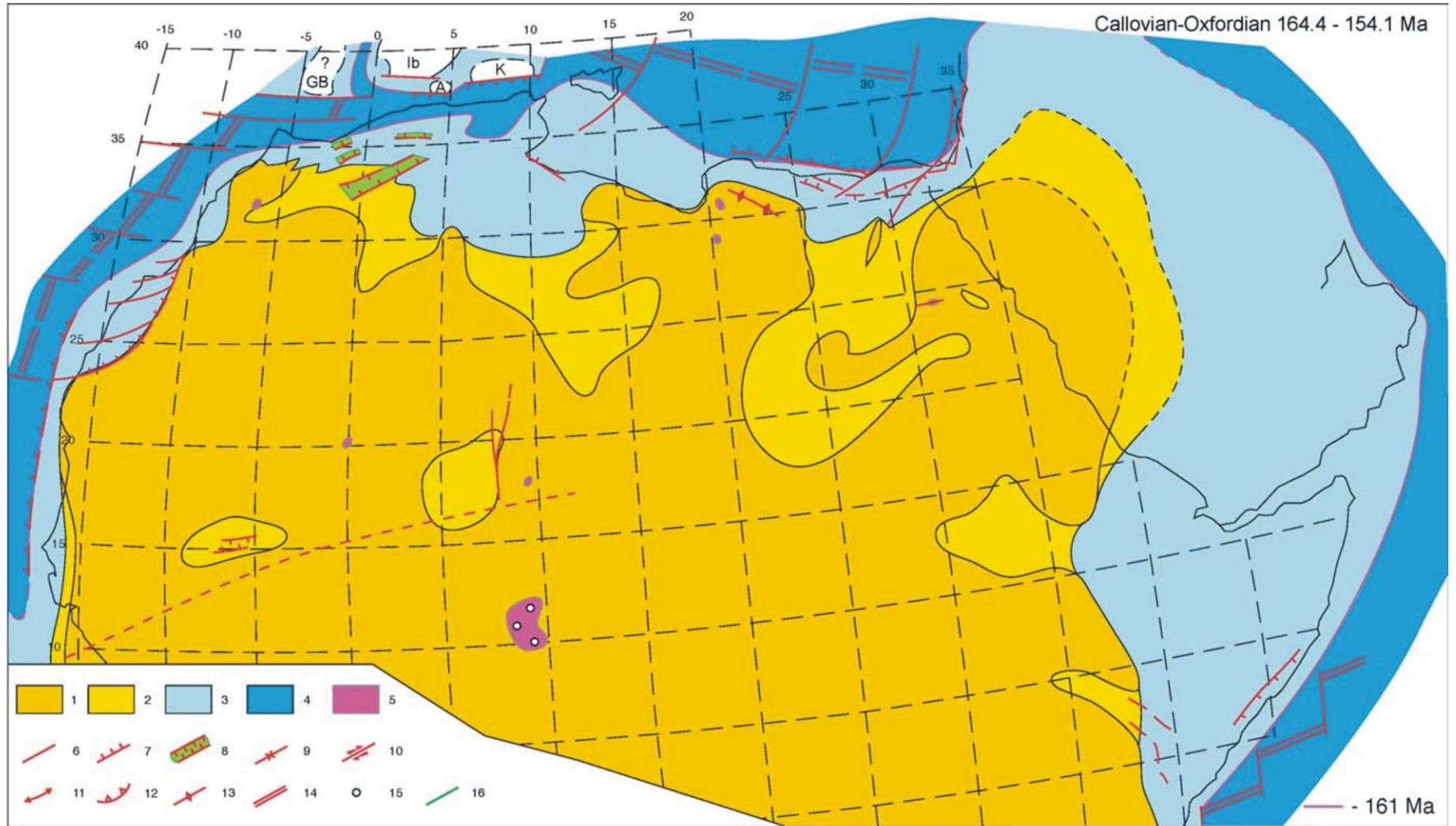
Сближение континентов и микроконтинентов. Северные окраины всех океанических бассейнов становятся активными, с субдукцией океанической коры. Над ними, на южных окраинах всех микроконтинентов – вулкано-плутонические пояса, субвулканические дуги. Ширина океанических бассейнов резко сокращается. Австрийская фаза мезозойской складчатости. Офиолитовые швы. Над ними – узкие междугловые бассейны с накоплением флиша в K₂-Pg. Островодужная, позднегеосинклинальная стадия развития для всего Тетиса.

Late Jurassic 152 Ma

Секвенции фанерозоя НГБ
Северной Африки



Секвенции фанерозоя НГБ Северной Африки



A

Fig. Callovian–Oxfordian (164.4–154.1 Ma) paleogeological map

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Секвенции фанерозоя НГБ Северной Африки

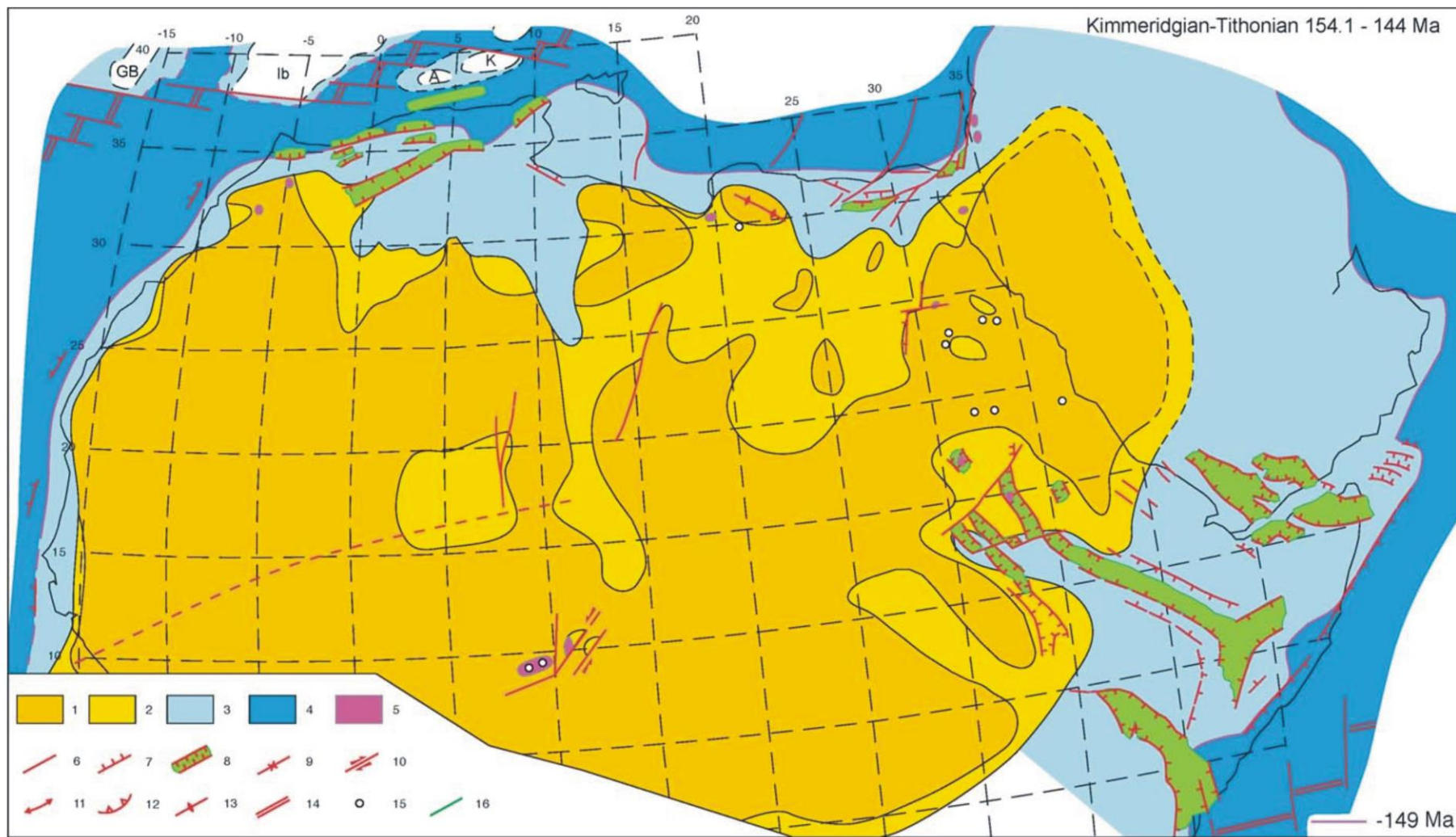
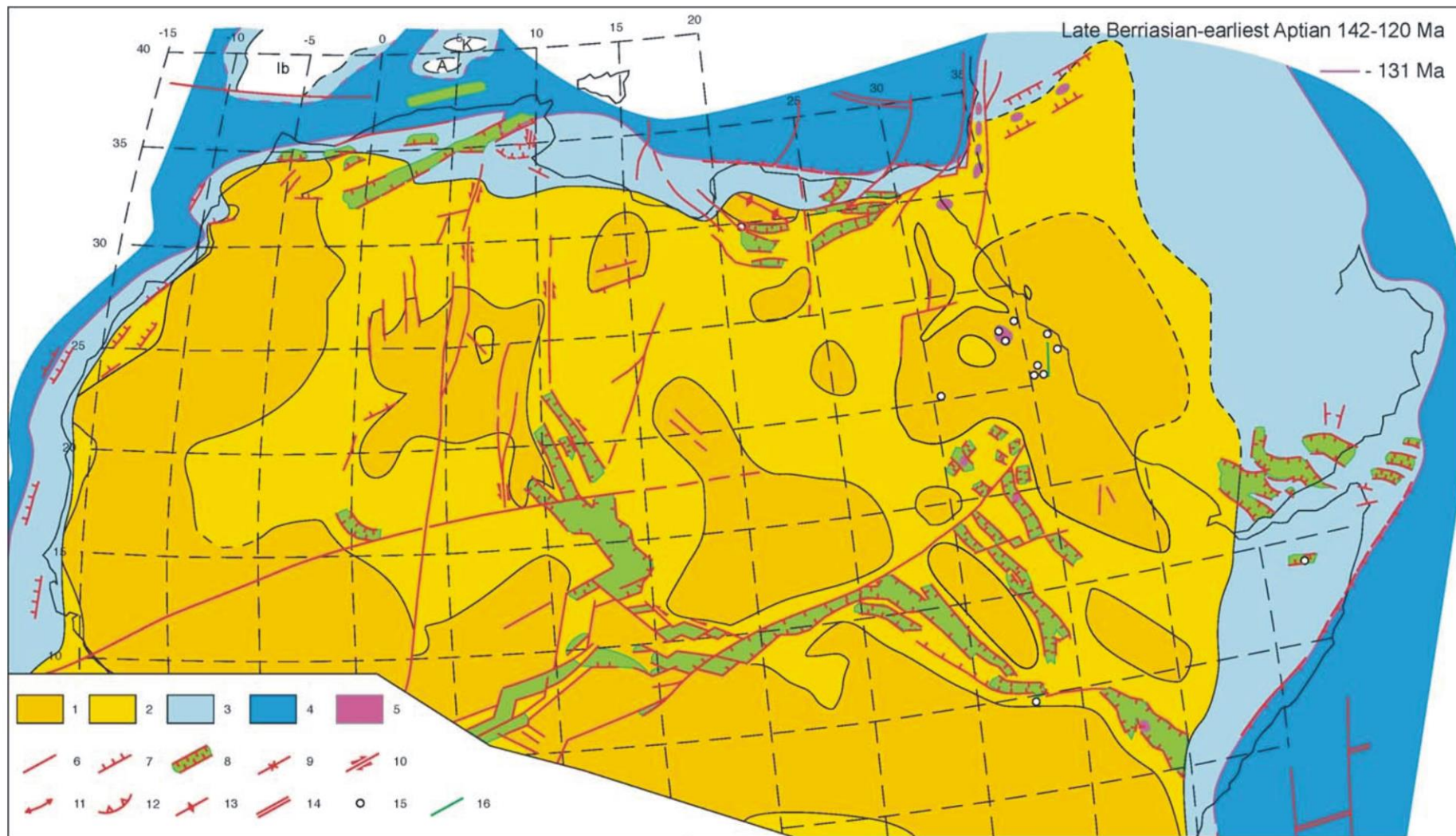


Fig. Kimmeridgian–Early Berriasian (154.1–142 Ma) paleogeological map **B**

Секвенции фанерозоя НГБ Северной Африки



A

A, Alboran; Ib, Iberia; K, Kabylies.

Fig. Late Berriasian–earliest Aptian (142–120 Ma) paleogeological map

Секвенции фанерозоя НГБ Северной Африки

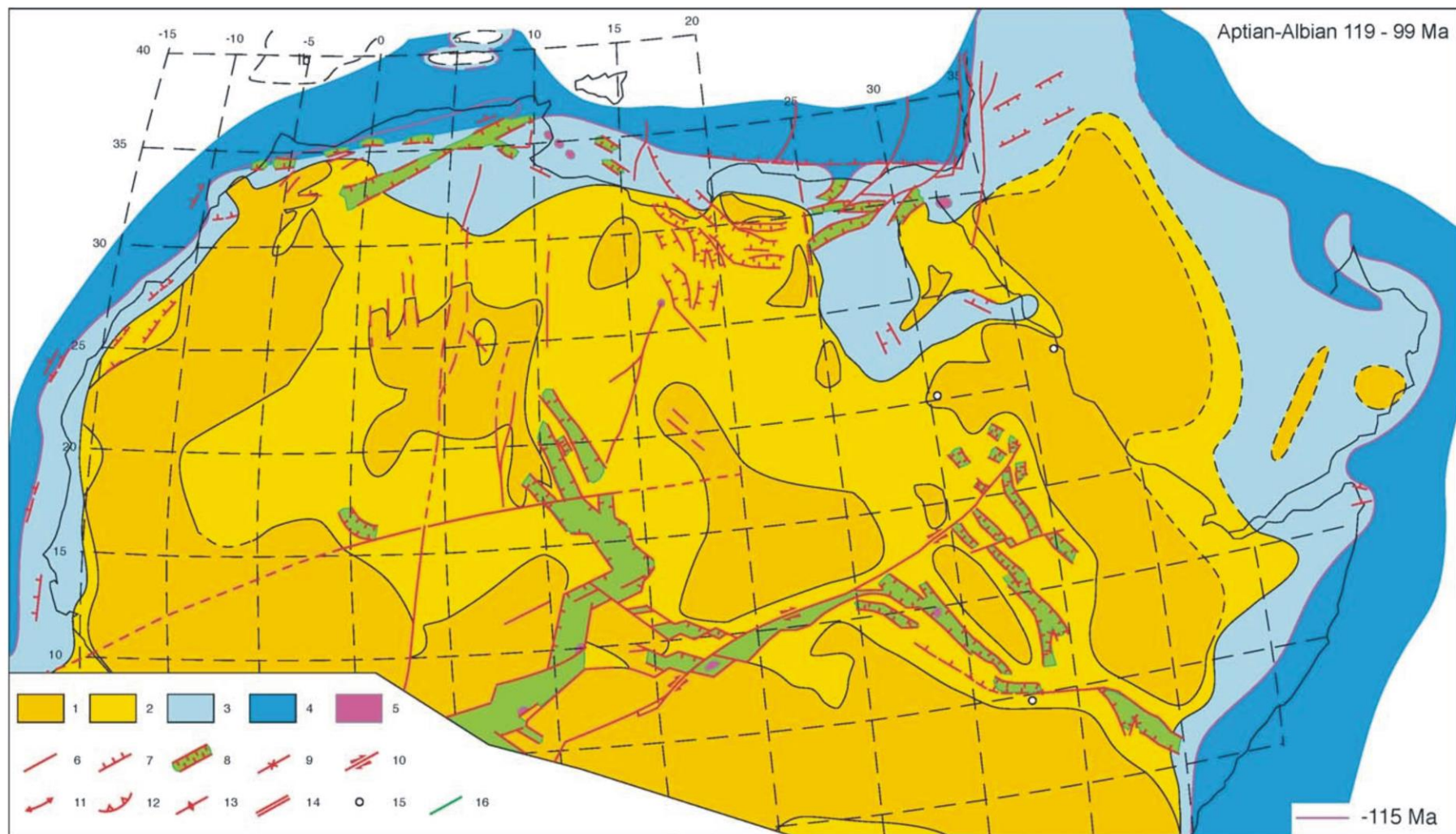


Fig. Aptian–Albian (119–99 Ma) paleogeological map

B

Секвенции фанерозоя НГБ Северной Африки

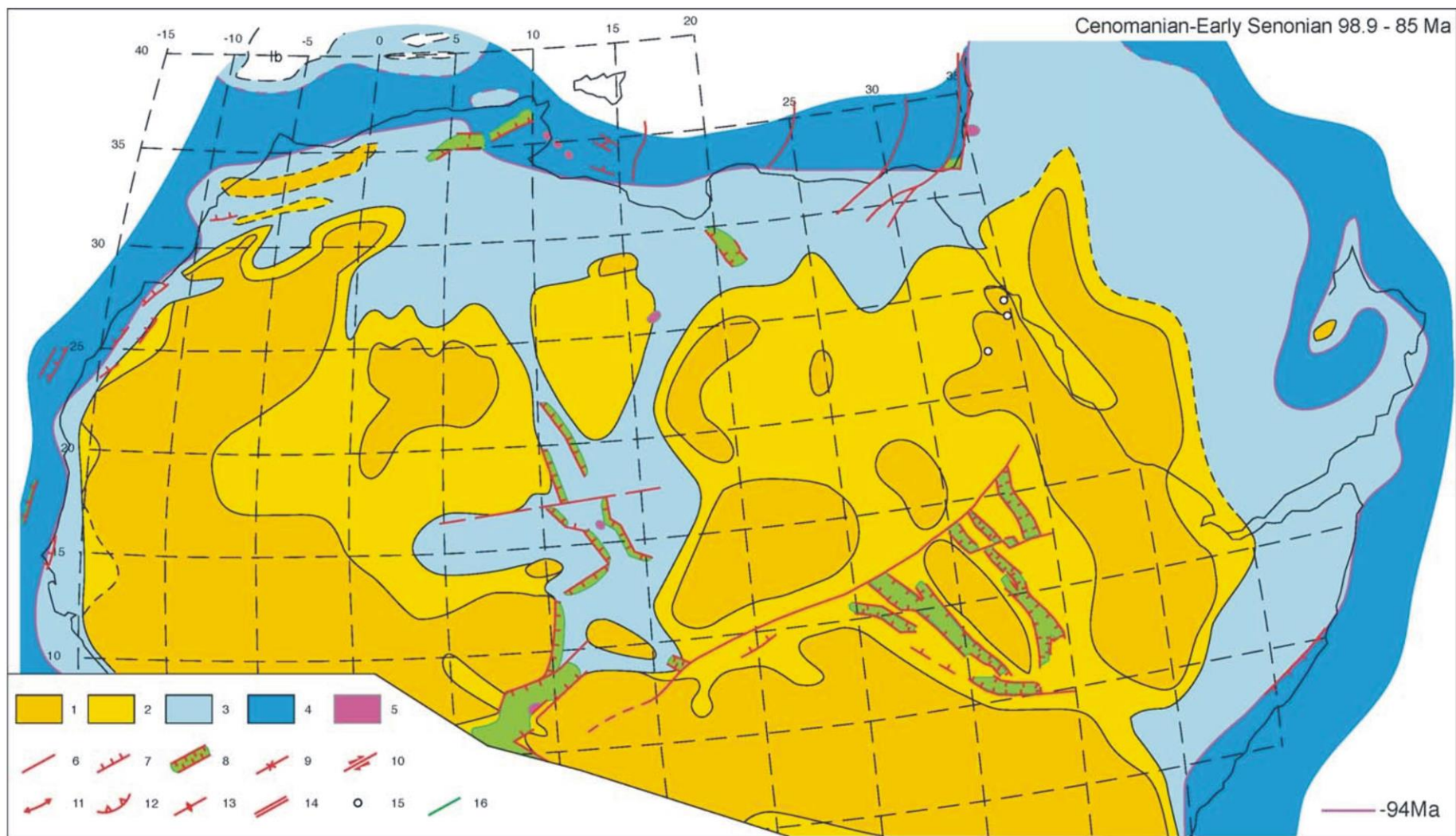
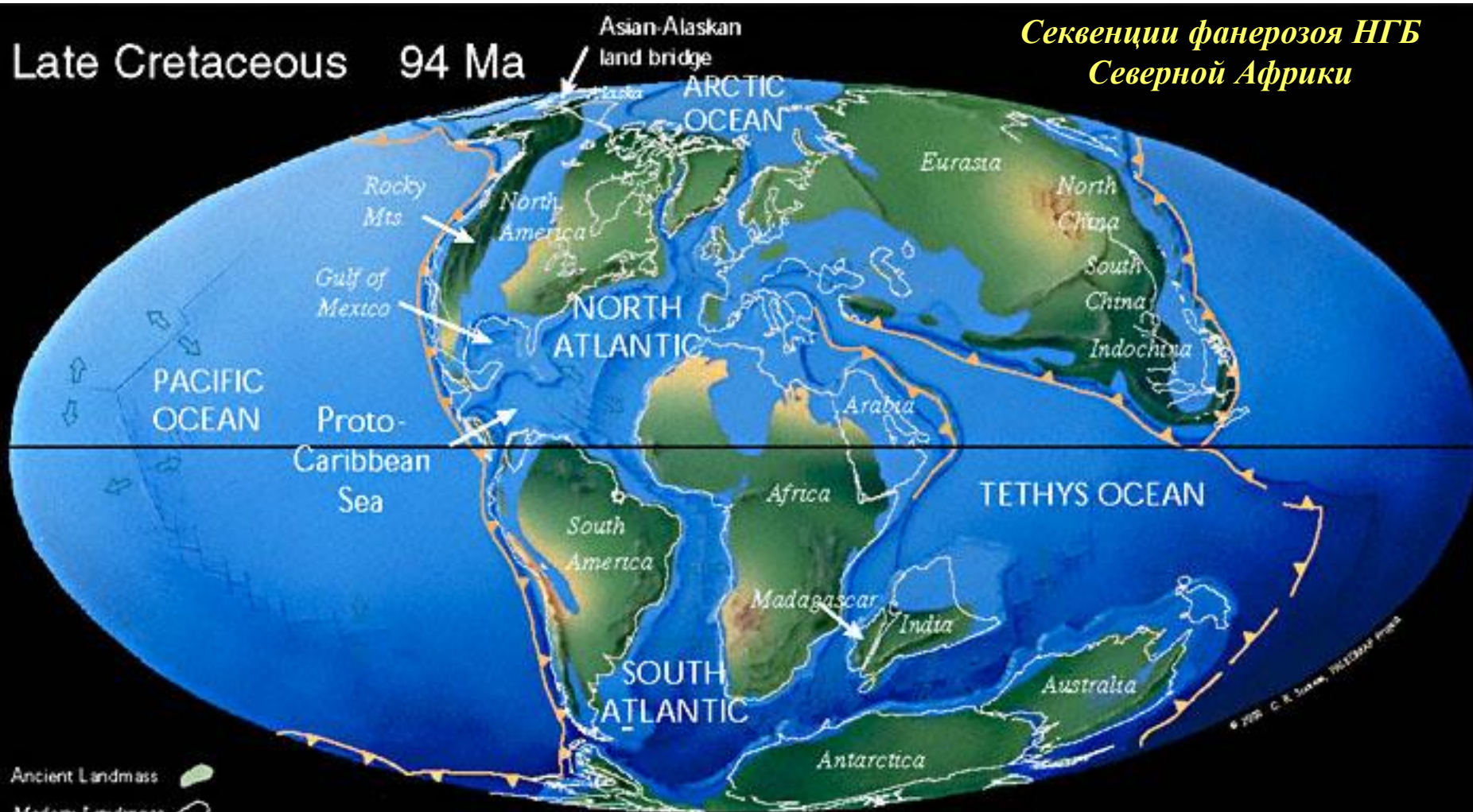


Fig. Latest Albian–Early Senonian (98.9–85 Ma) paleogeological map **A**

Late Cretaceous 94 Ma

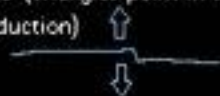
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Ancient Landmass

Modern Landmass

Subduction Zone (triangles point in the direction of subduction)



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Секвенции фанерозоя НГБ Северной Африки

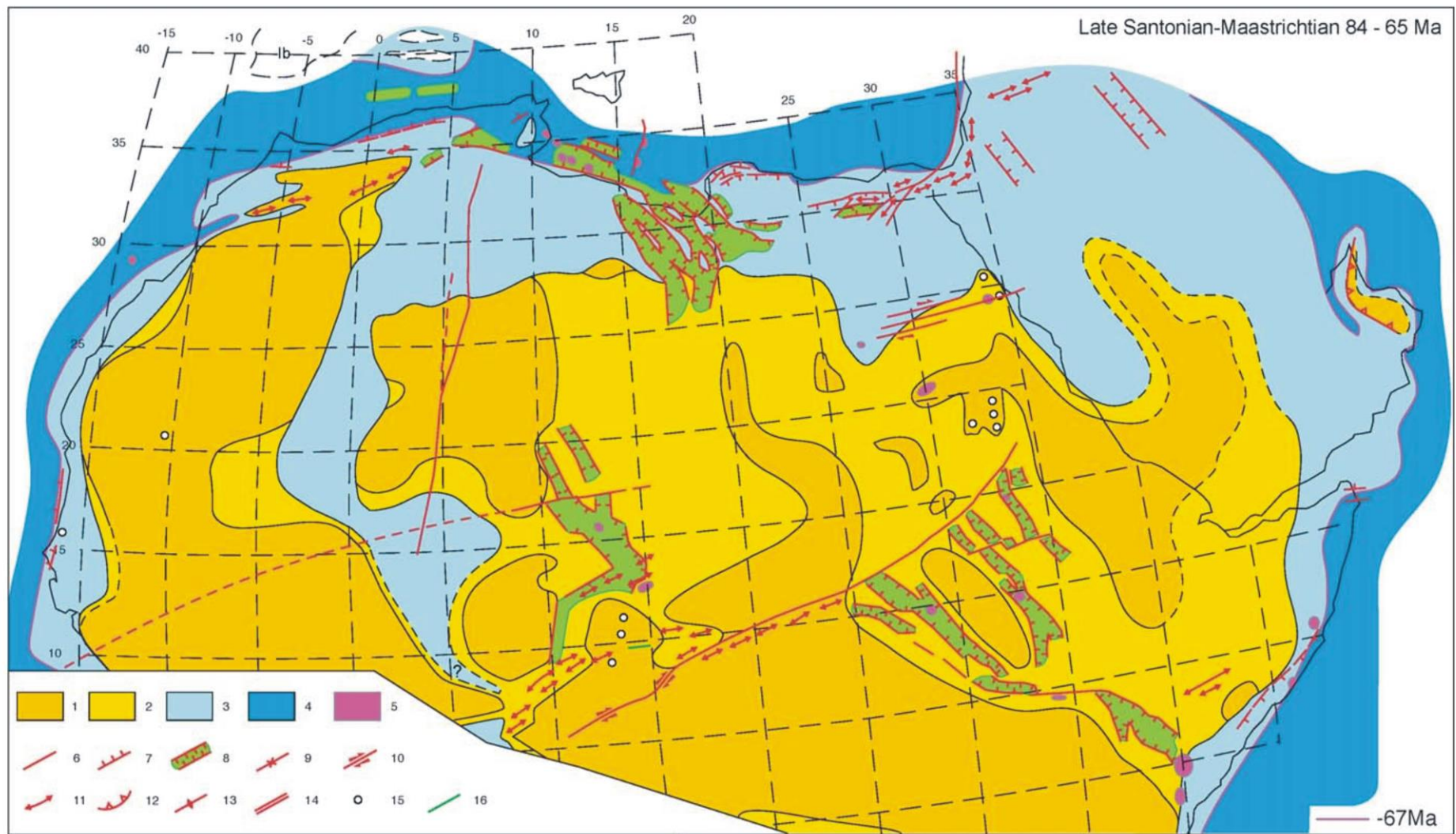
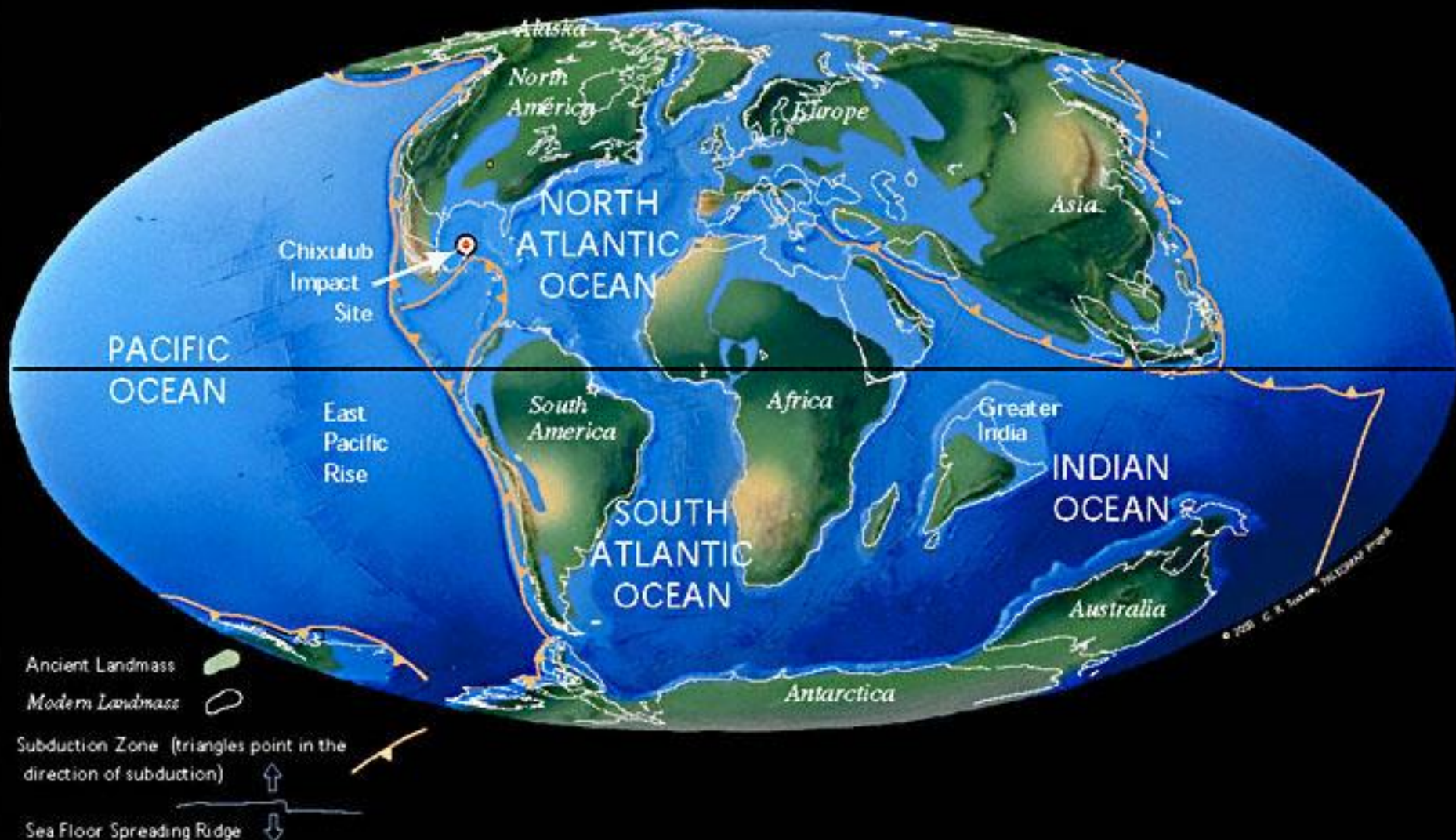
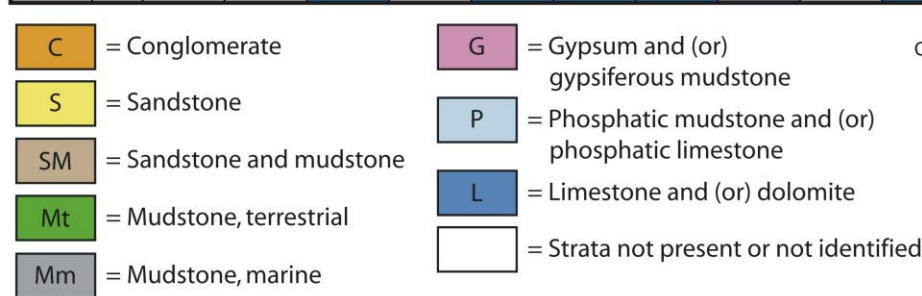
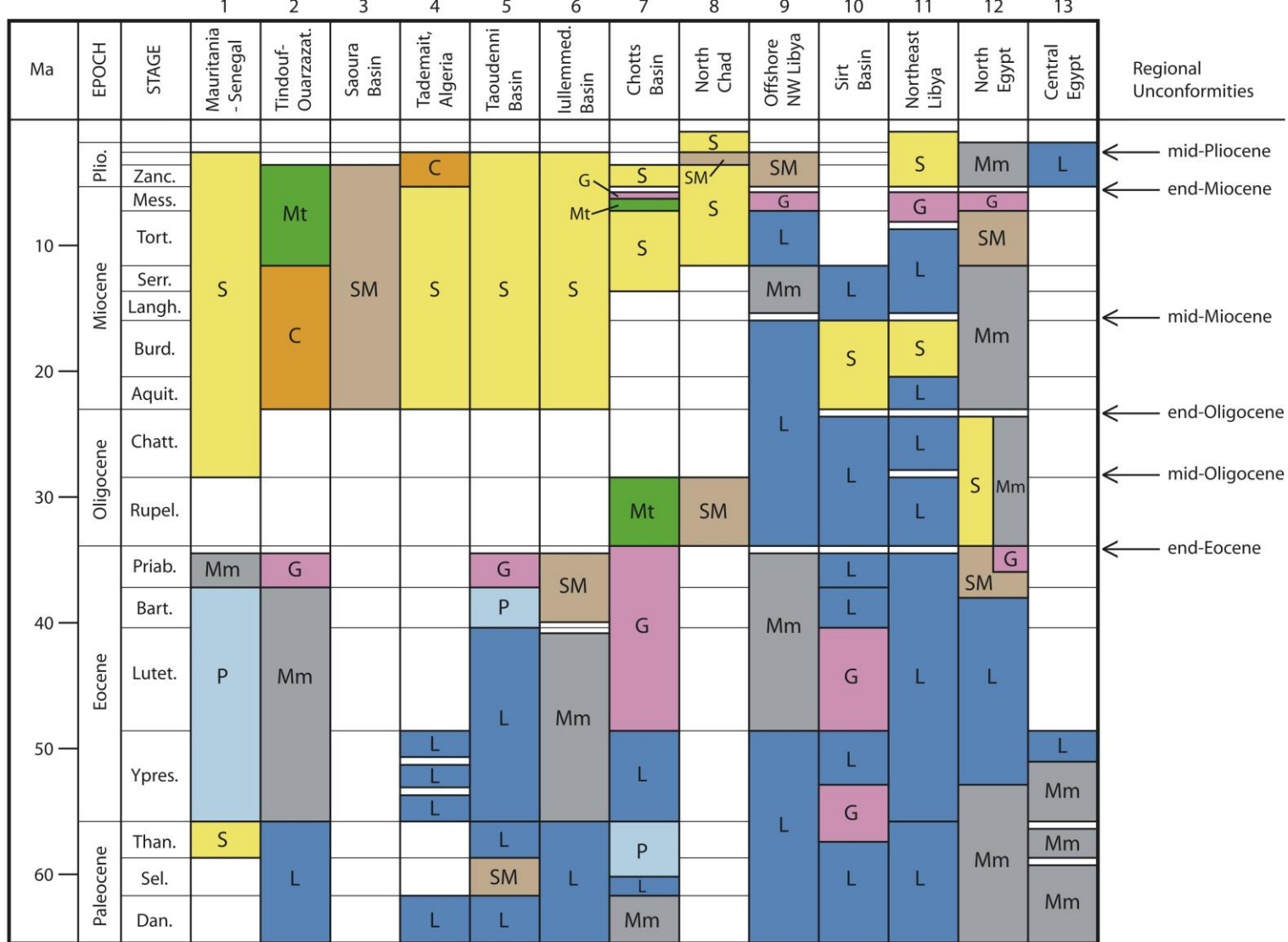


Fig. Late Santonian–Maastrichtian (84–65 Ma) paleogeological map **B**

K/T Boundary 66 Ma

*Секвенции фанерозоя НГБ
Северной Африки*



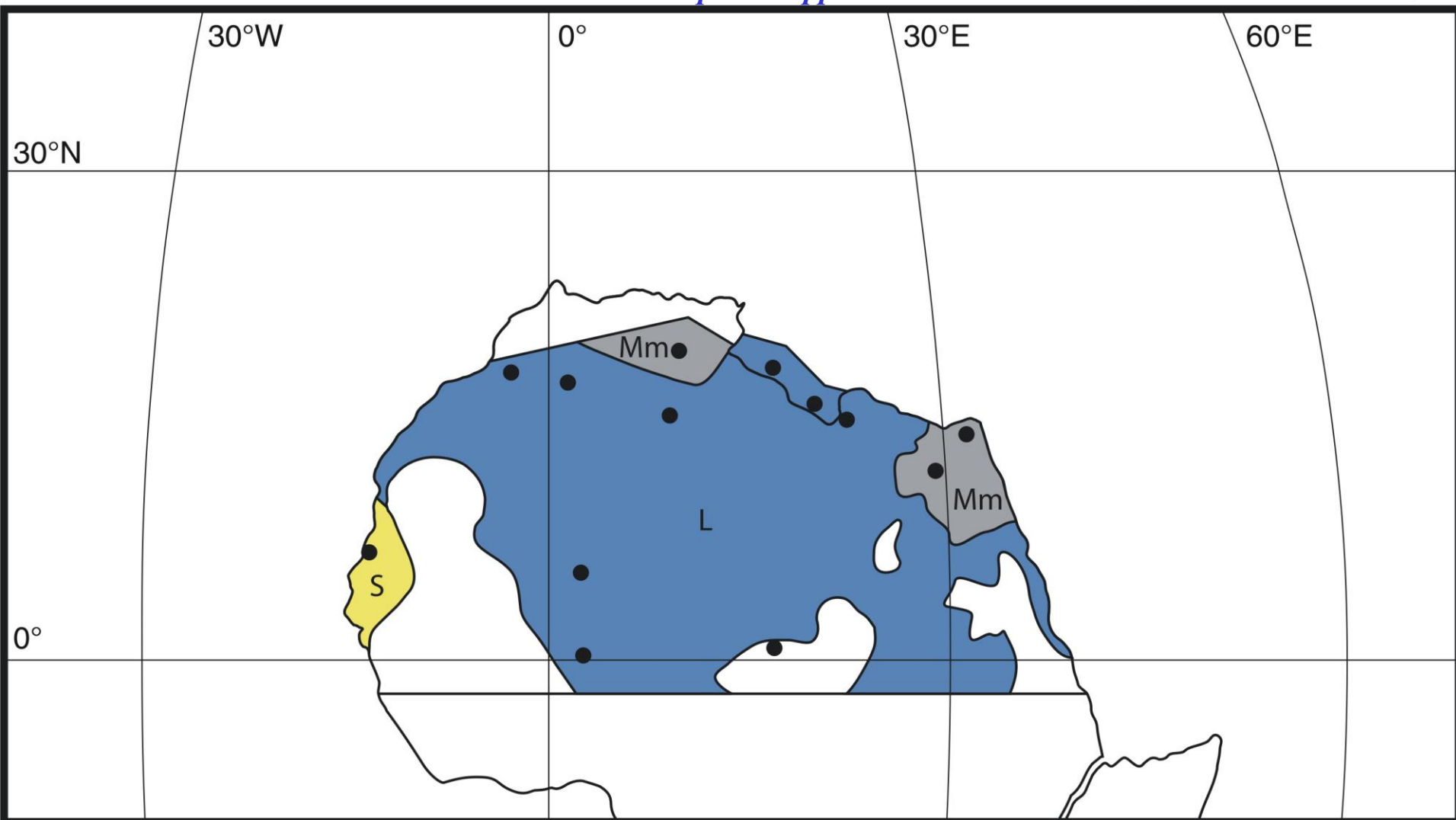


C.S. Swezey / Journal of African Earth Sciences 53 (2009) 89–121

Predominant lithologies and regional unconformities of Cenozoic strata in the Sahara. The numbers at the tops of the columns denote location numbers shown in previous figure

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Северной Африки*

Paleocene (Danian-Thaneltian)



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Paleogeographic setting of the Sahara during the Paleocene (Danian–Thaneltian)

Секвенции фанерозоя НГБ Северной Африки

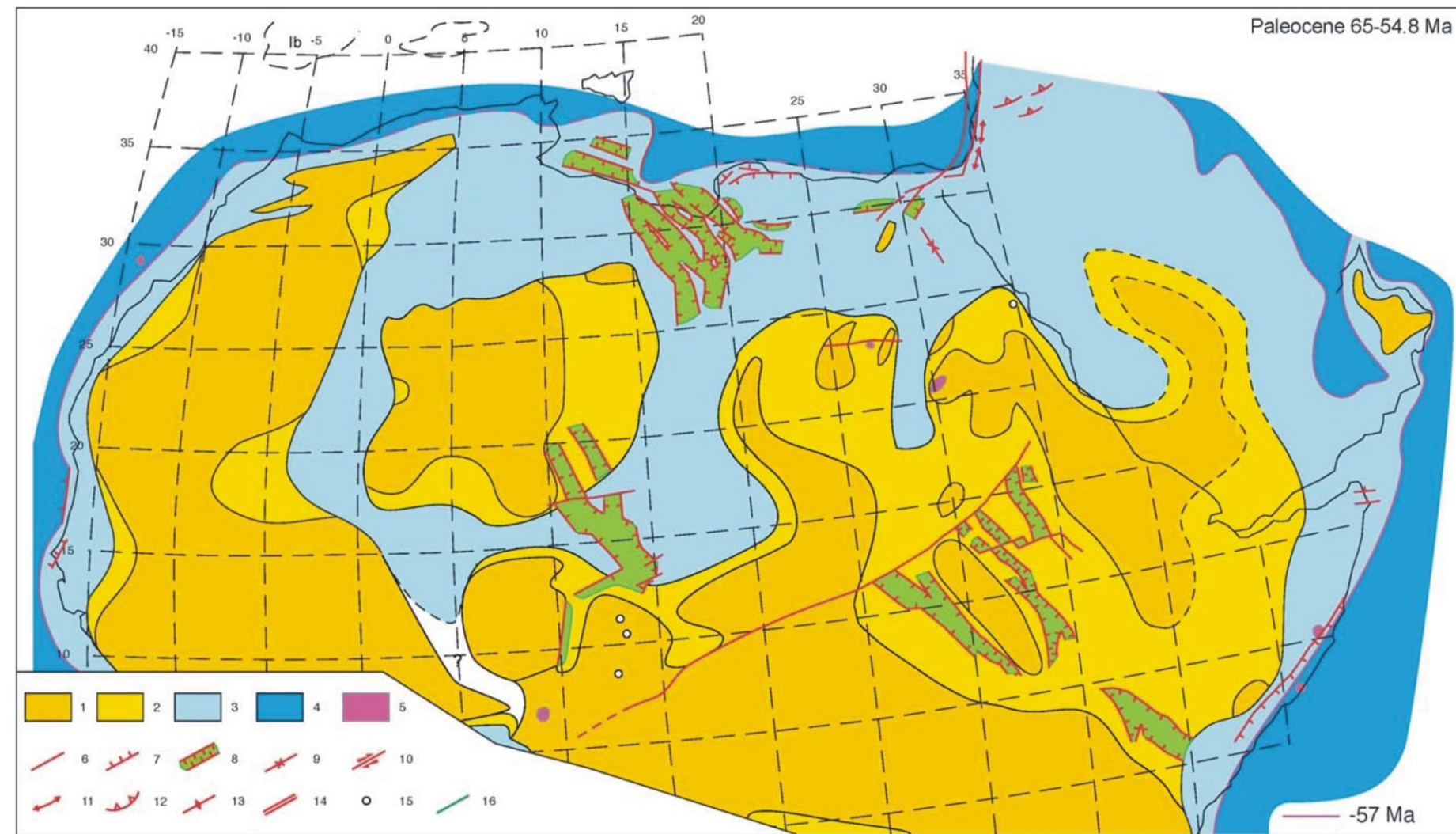
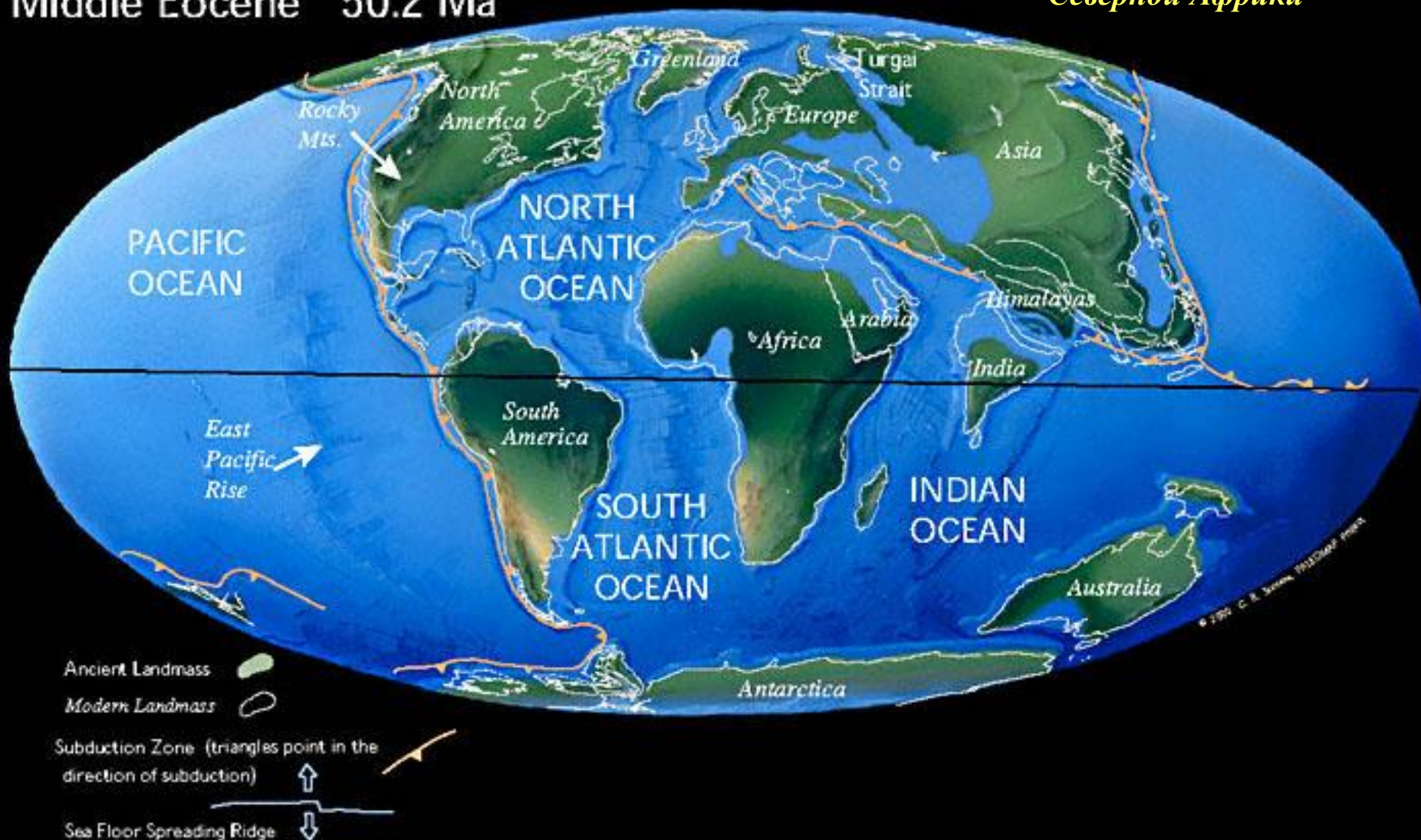


Fig. Paleocene (65–54.8 Ma) paleogeological map

A

Middle Eocene 50.2 Ma

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Секвенции фанерозоя НГБ Северной Африки

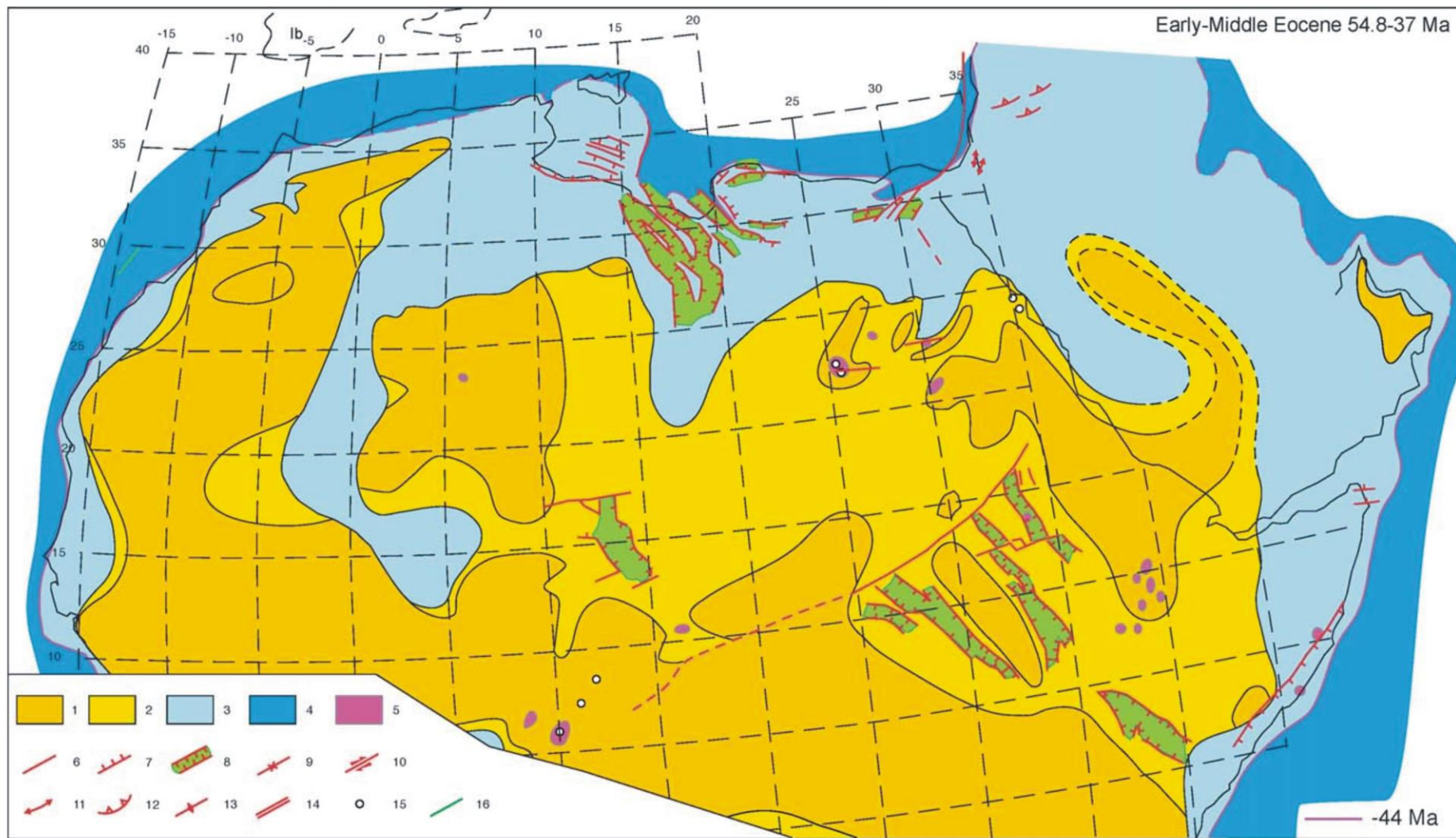
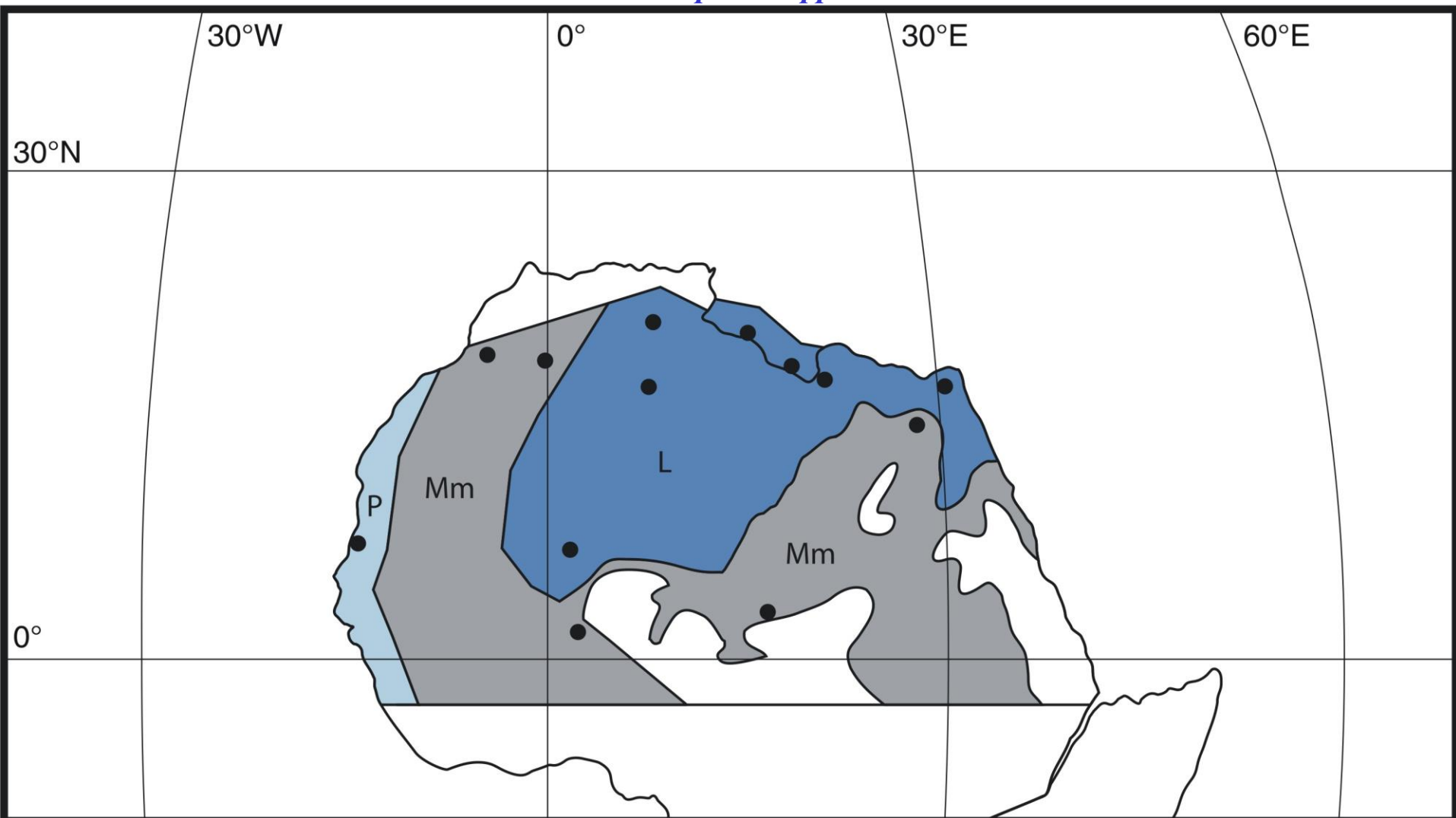


Fig. Early-Middle Eocene (54.8–37 Ma) paleogeological map

B

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Early Eocene (Ypresian)

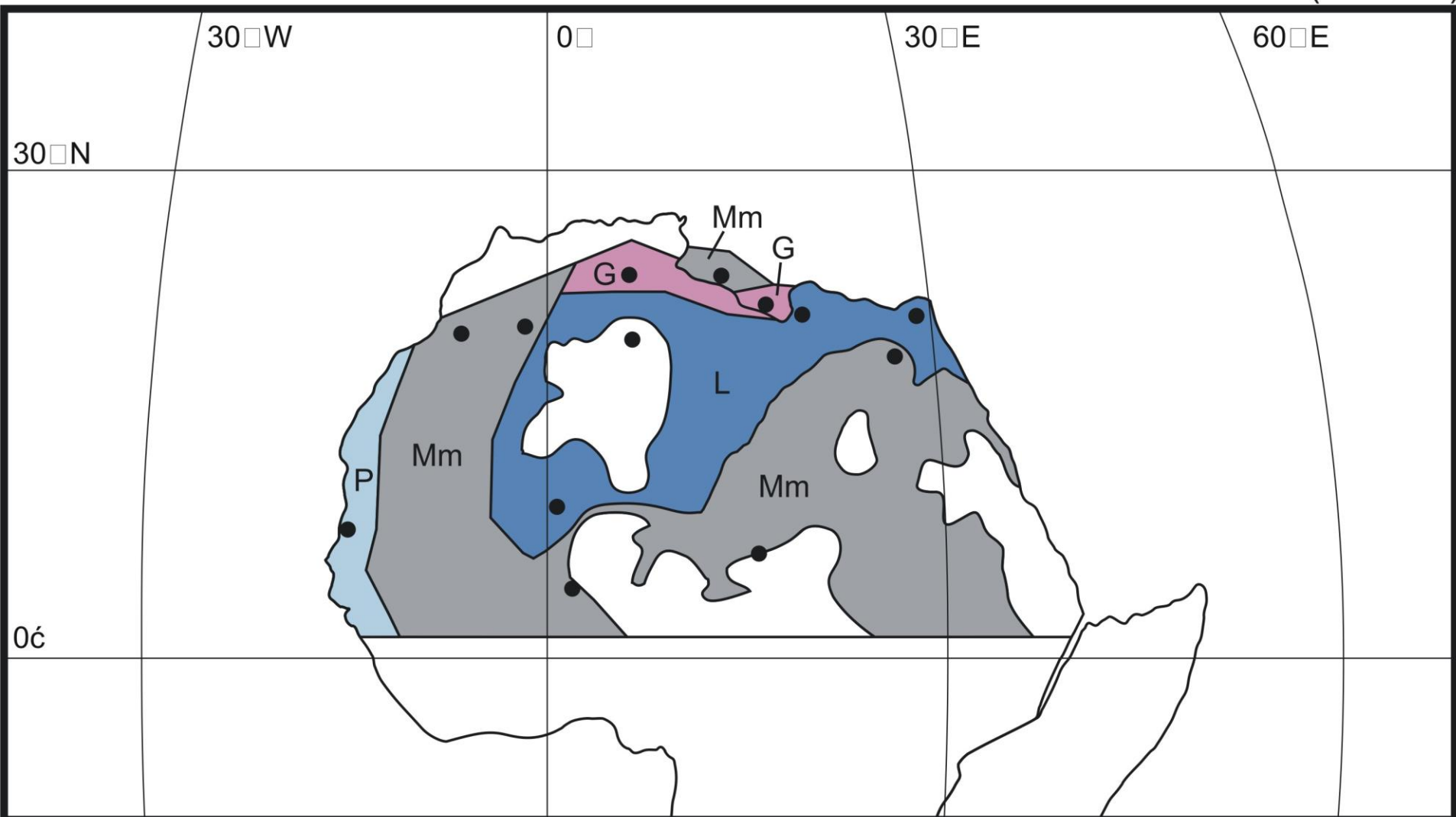


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Paleogeographic setting of the Sahara during the Early Eocene (Ypresian)

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Middle Eocene (Lutetian)

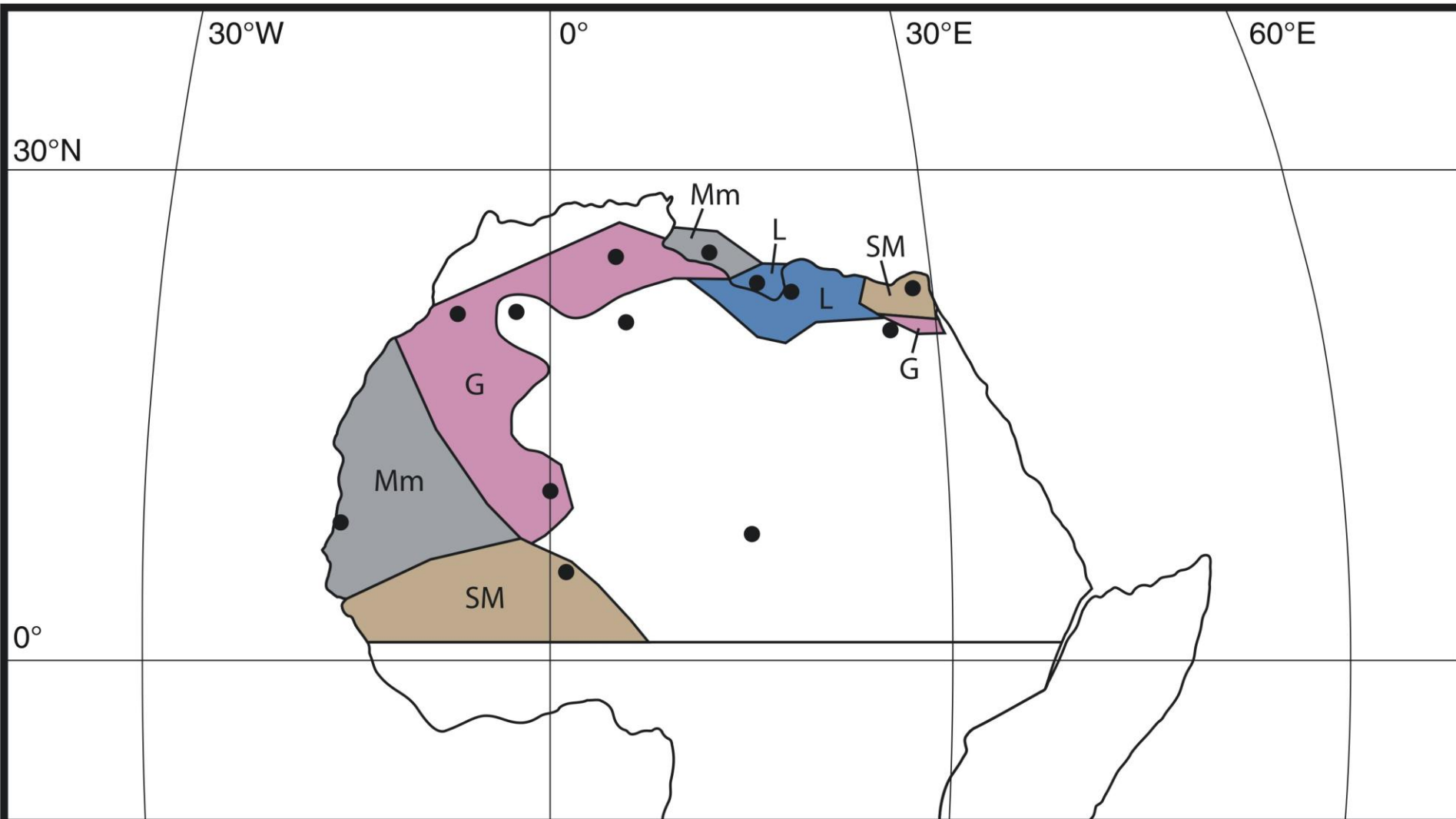


Paleogeographic setting of the Sahara during the Middle Eocene (Lutetian)

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Северной Африки*

Late Eocene (Priabonian)



Paleogeographic setting of the Sahara during the Late Eocene (Priabonian)

Секвенции фанерозоя НГБ Северной Африки

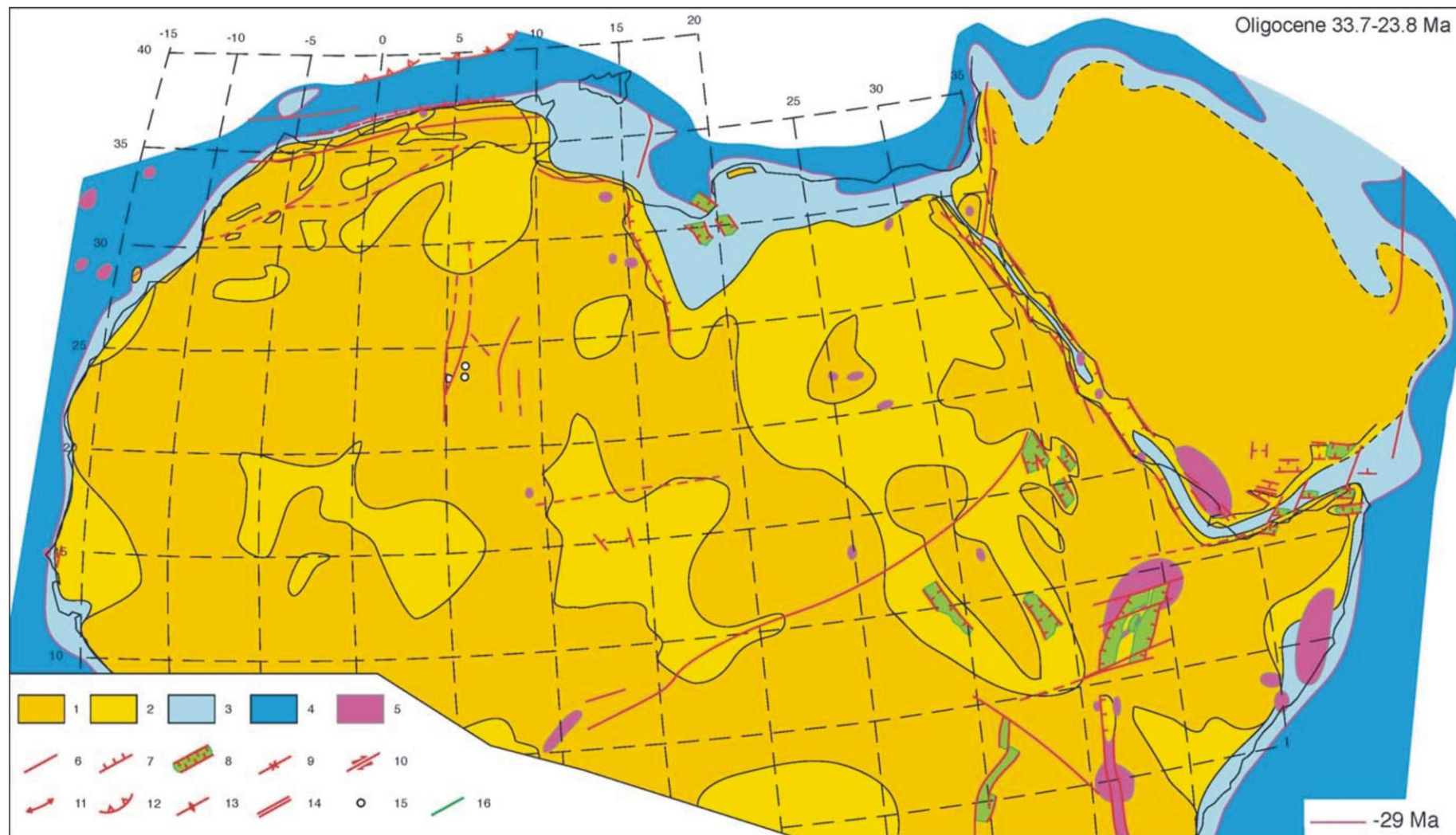


Fig. Oligocene (33.7–23.8 Ma) paleogeological map

A

Секвенции фанерозоя НГБ Северной Африки

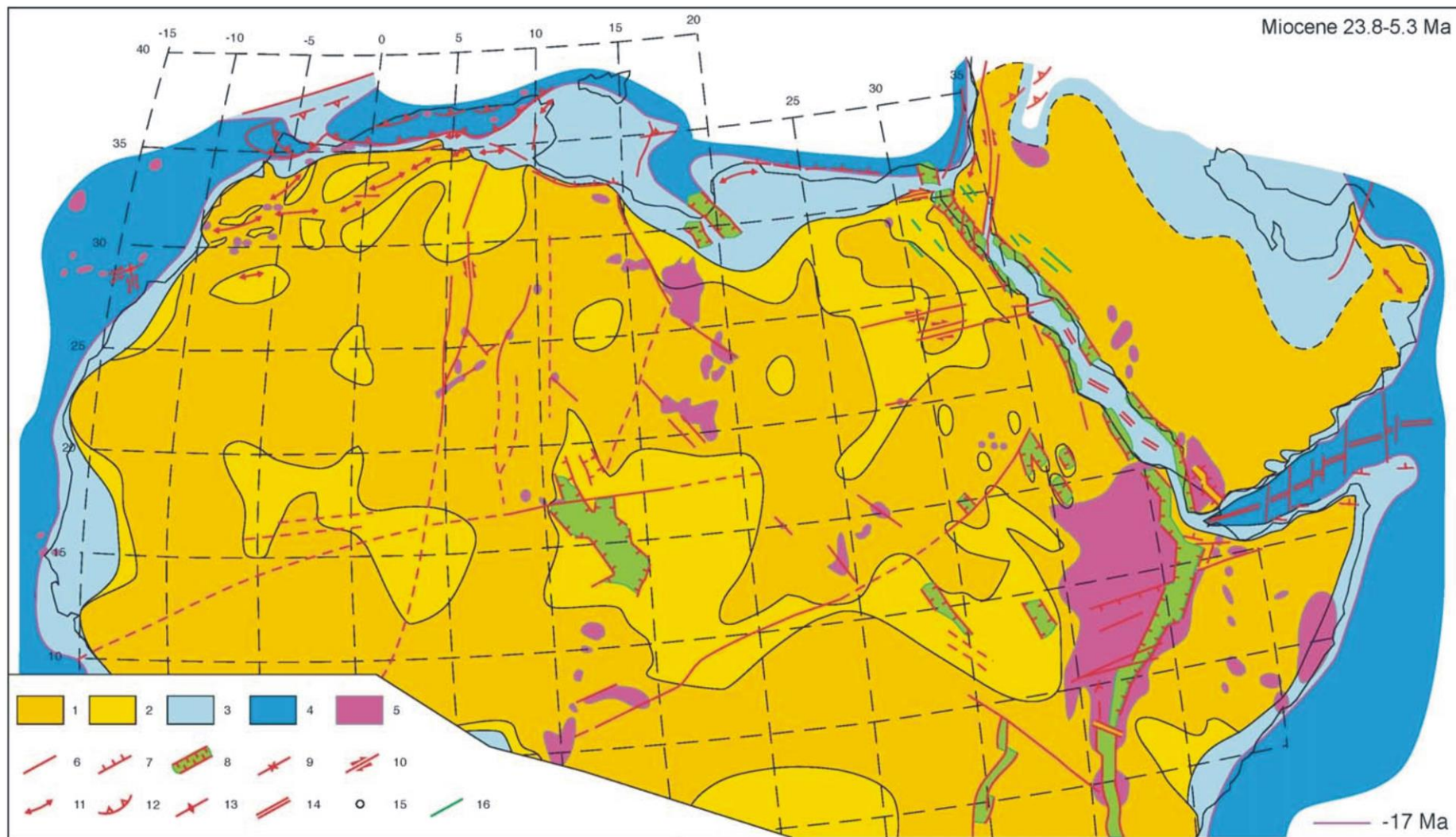
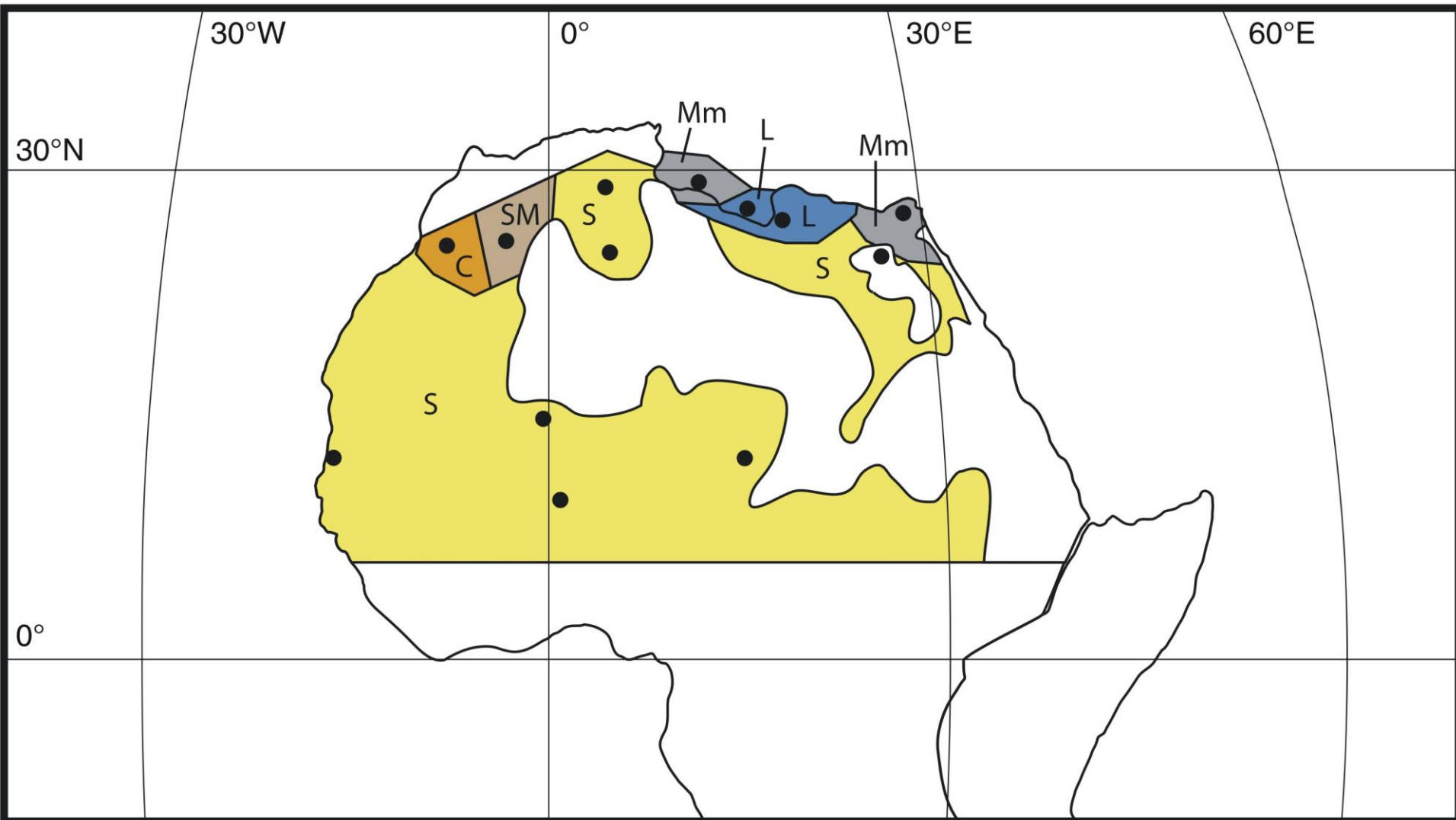


Fig. Miocene (23.8–5.3 Ma) paleogeological map

B

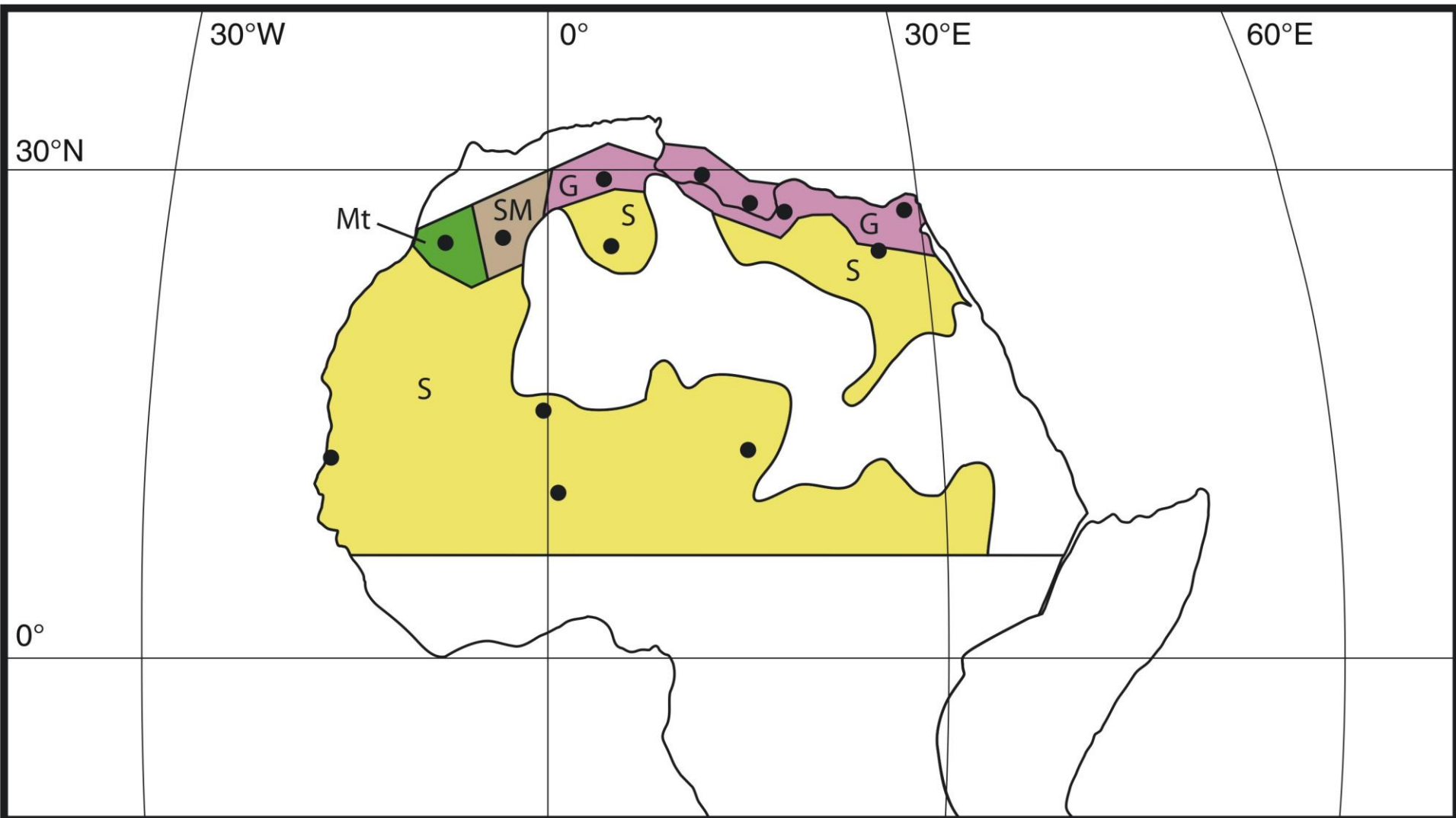


Paleogeographic setting of the Sahara during the Middle Miocene (Langhian–Serravallian)

Секвенции фанерозоя НГБ

Северной Африки

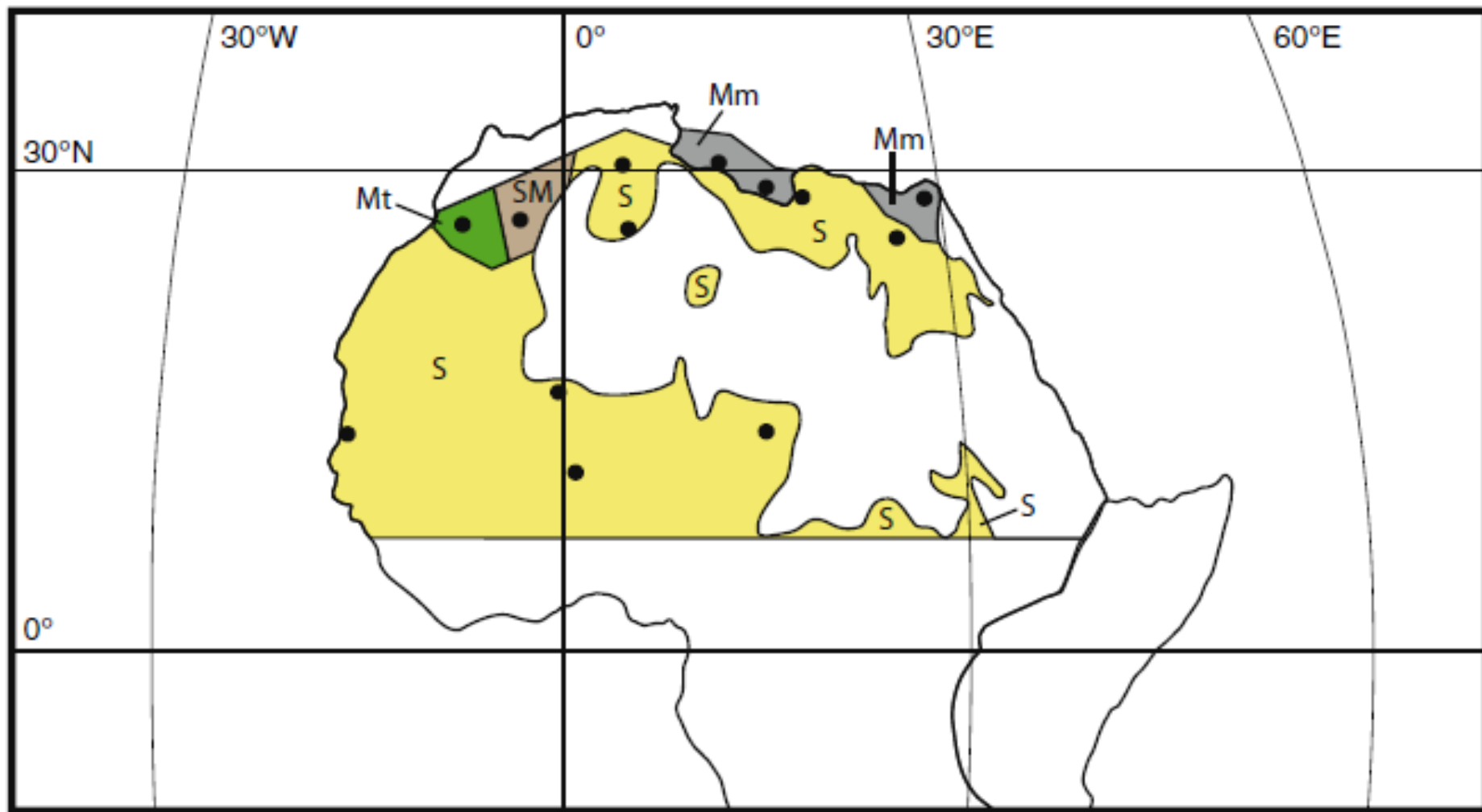
Latest Miocene (Latest Messinian)



Paleogeographic setting of the Sahara during the latest Miocene (latest Messinian)

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*Секвенции фанерозоя НГБ
Северной Африки*



Early Pliocene (Zanclean)

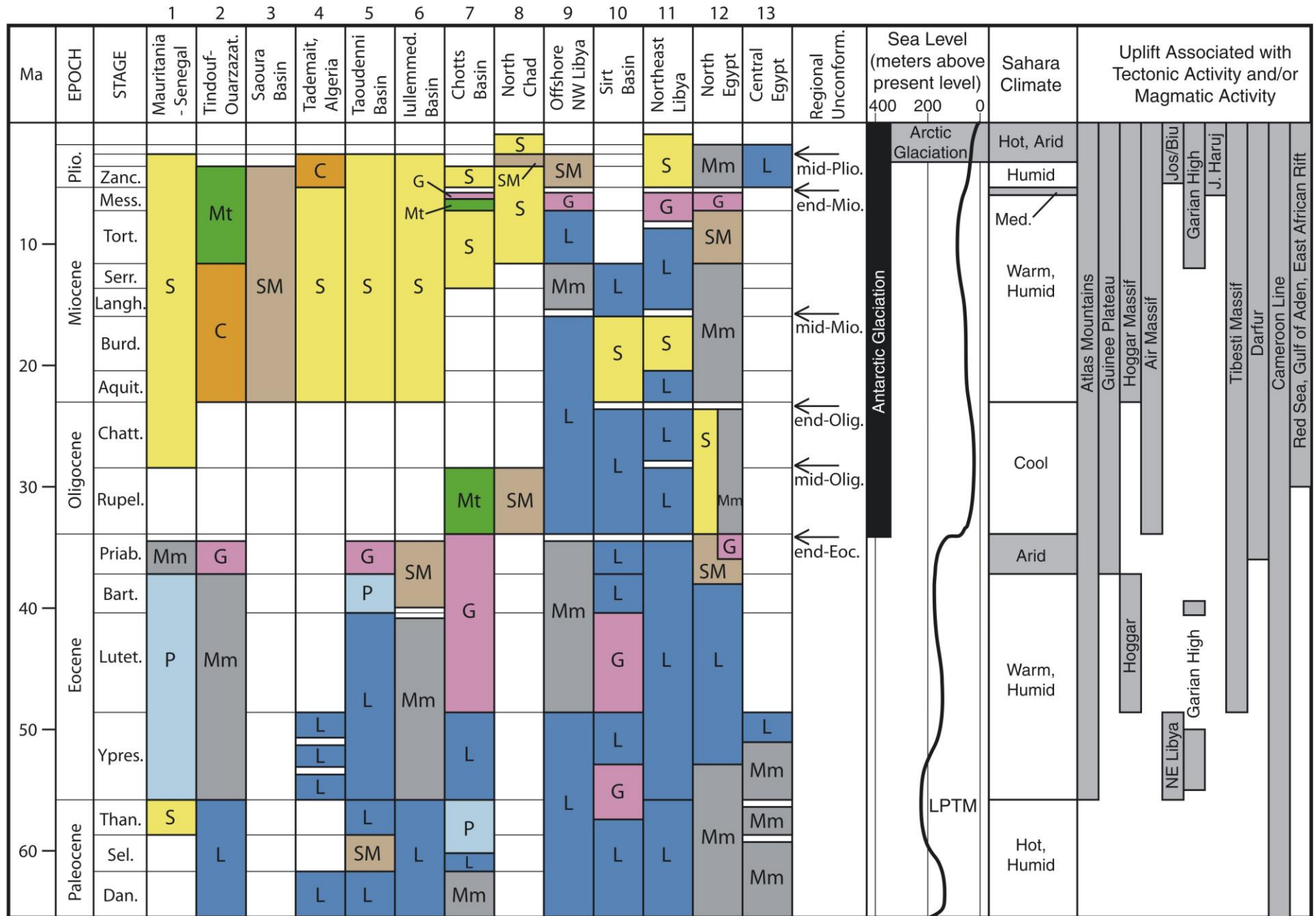


Chart showing the Cenozoic stratigraphy of the Sahara in relation to changes in eustatic sea level, polar glacial events, Saharan climate, and tectonic activity around northern Africa. . LPTM = Late Paleocene Thermal Maximum; Med. = Desiccation of the Mediterranean Sea; Unconform. = Unconformities.

Last Glacial Maximum 18,000 years ago

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- Ancient Landmass
- Modern Landmass
- Subduction Zone (triangles point in the direction of subduction)
- Sea Floor Spreading Ridge

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Секвенции фанерозоя НГБ Северной Африки

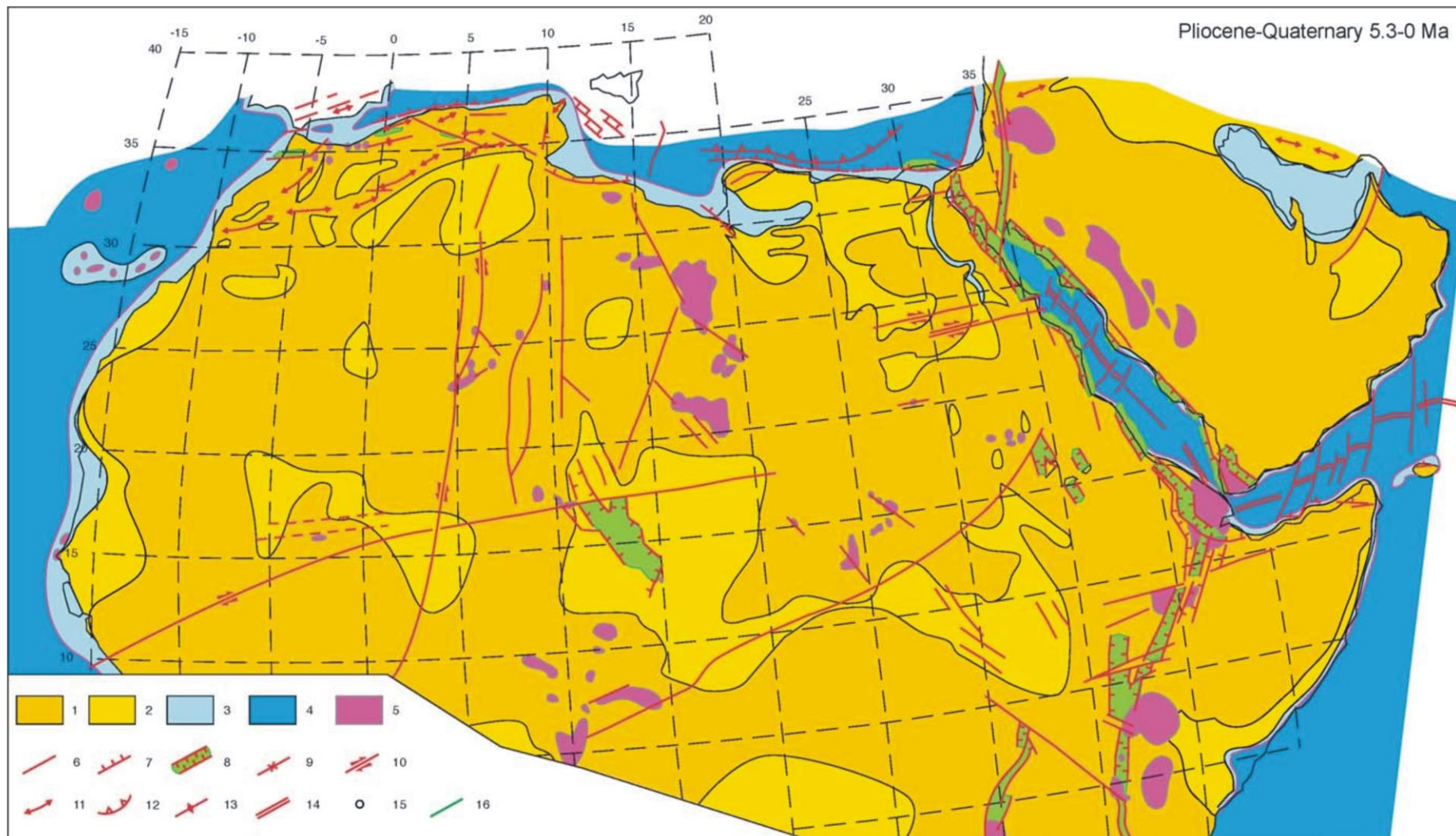
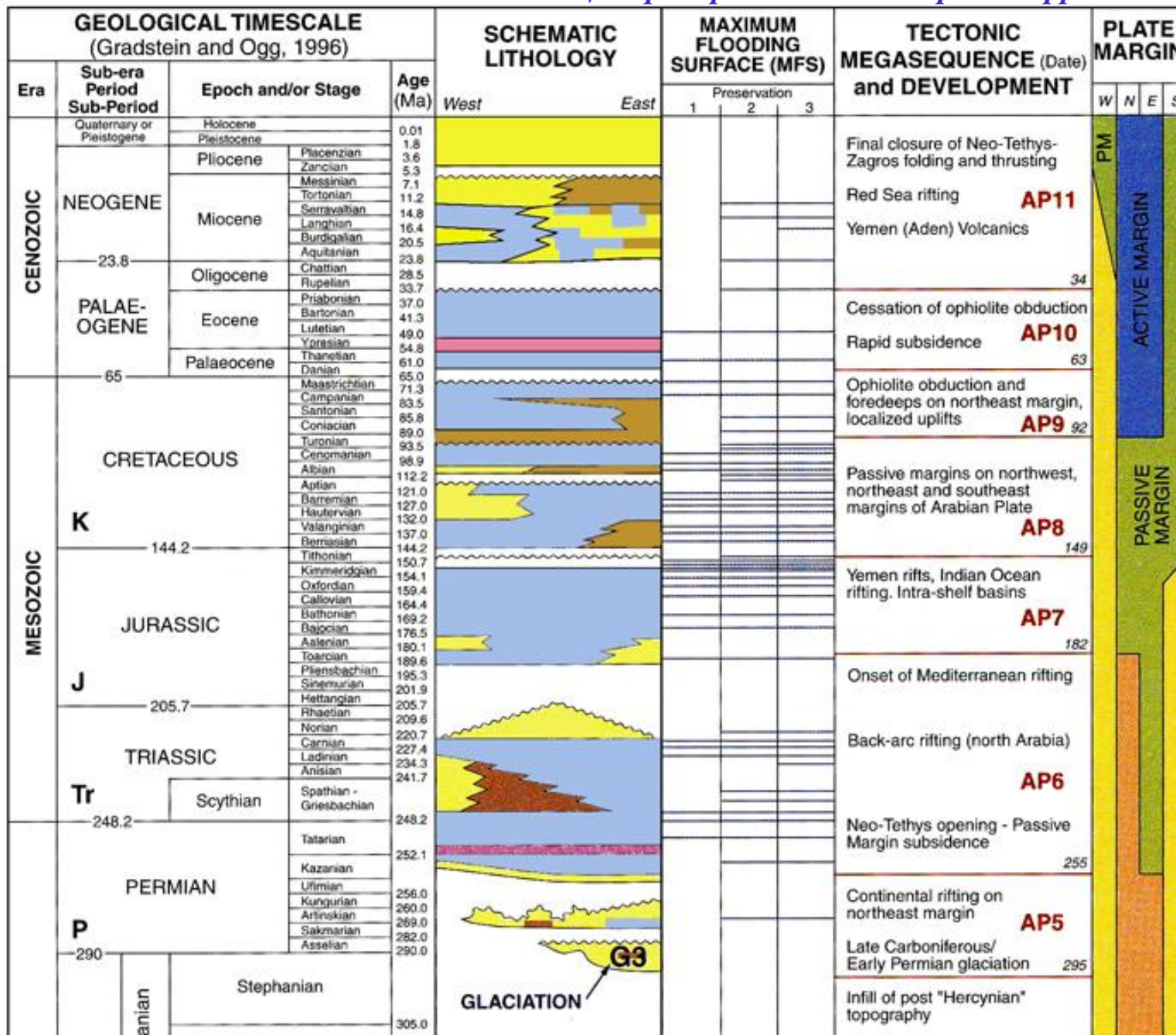


Fig. Pliocene-Quaternary (5.3–0 Ma) paleogeological map

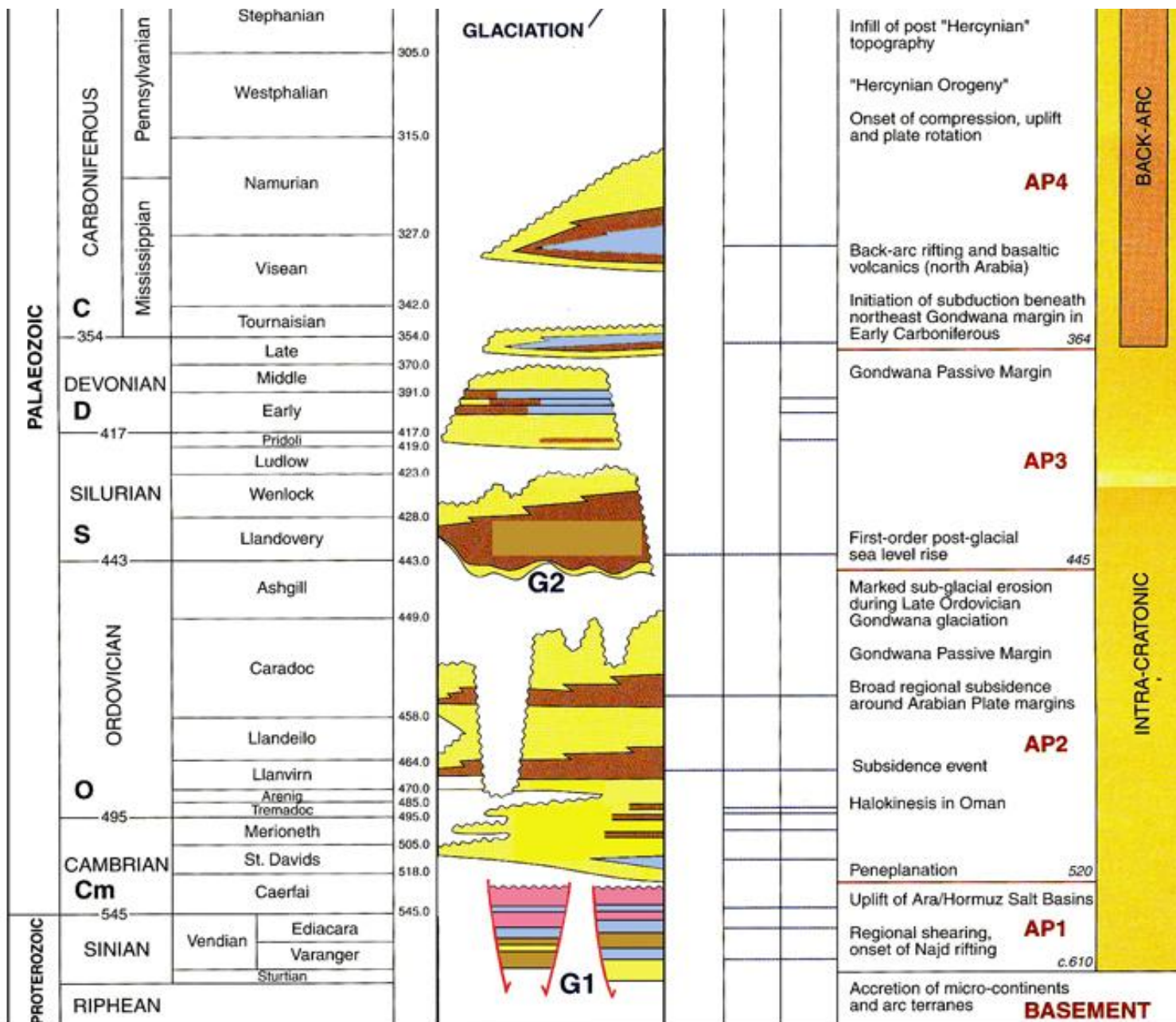
Секвенции фанерозоя НГБ Северной Африки



Геологическая
история
Северной Африки

Секвенции фанерозоя НГБ Северной Африки

Геологическая история Северной Африки



Лекция 4. Секвенции фанерозоя НГБ Северной Африки

Выводы

- 1. Северная Африка имеет сложное гетерогенное строение (древние платформы и орогенные пояса разного возраста - байкалиды, герциниды, альпиды)*
- 2. В истории этого региона можно выделить ряд этапов: формирование Гондваны к концу докембрия и ее наращивание до Пангеи-2 к концу палеозоя, ее распад в начале мезозоя в момент возрождения Средиземноморского пояса и образования молодых океанов.*
- 3. Северная окраина Гондваны всегда оставалась пассивной (без зон субдукции), эпизодически перекрывалась морскими водами вследствие морских трансгрессий из близлежащих океанов (Палеотетисе в палеозое, Тетисе и Атлантическом океане в мезо-кайнозое.*

Лекция 4. Секвенции фанерозоя НГБ Северной Африки

Рекомендуемая основная литература



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Phanerozoic geological evolution of Northern and Central Africa: An overview

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Лекция 4. Секвенции фанерозоя НГБ Северной Африки

Рекомендуемая основная литература

Journal of African Earth Sciences 53 (2009) 89–121

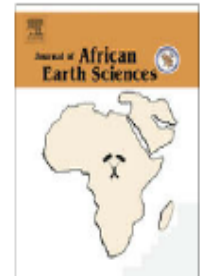


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Geological Society of Africa Presidential Review No. 13

Cenozoic stratigraphy of the Sahara, Northern Africa

Christopher S. Swezey *

US Geological Survey, 12201 Sunrise Valley Drive, MS 956, Reston, VA 20192, USA

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

План:

- 1. История изучения, разведки НГБ Ливии*
- 2. Характеристика НГБ Северной Африки и Ливии*
- 3. Нефтяные системы НГБ Северной Африки и Ливии*

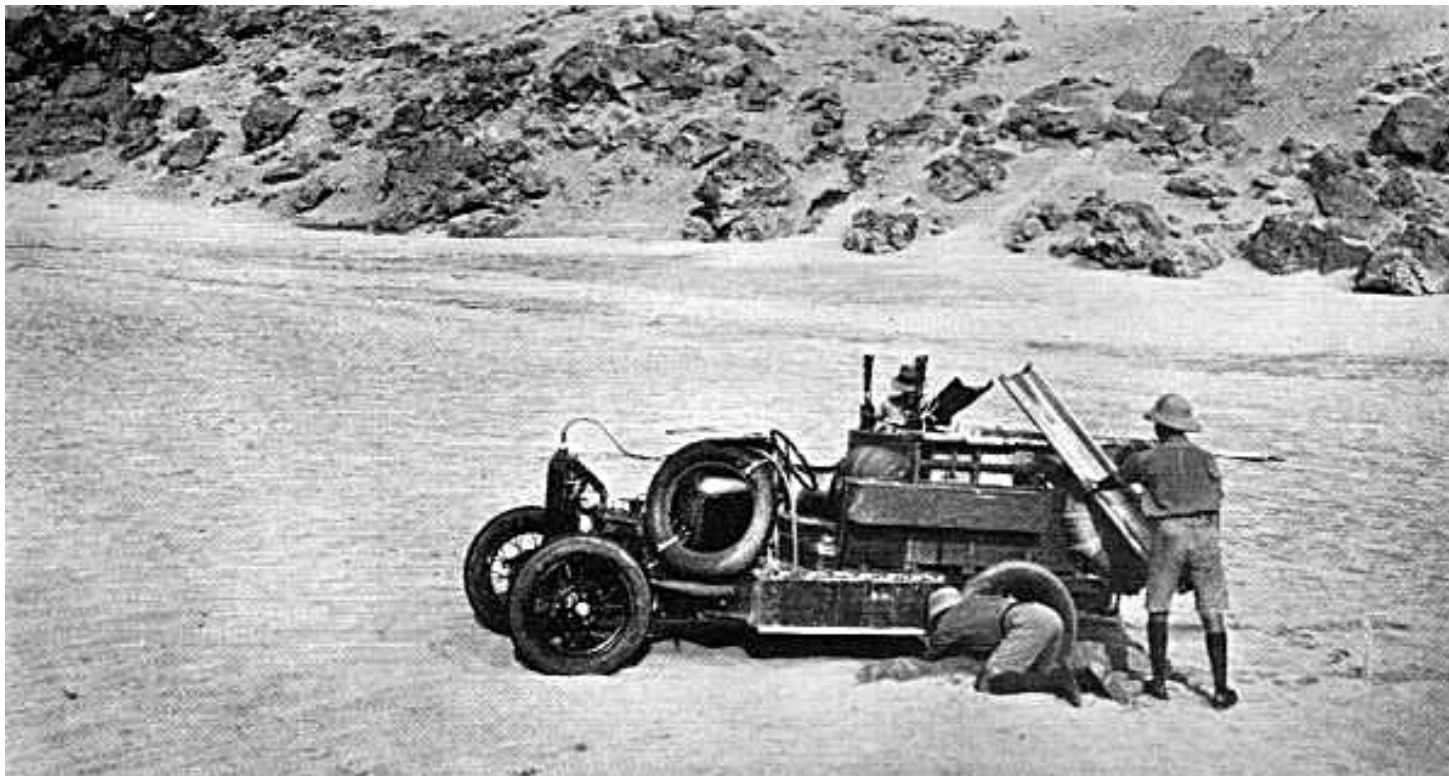


Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

История изучения



Before 1911 the natural resources of Libyan were under the control of the Turkish Empire. After 1911 until 1942 Italian colonist drove the geological exploration of Libya, and then from 1942 to 1951 a British administration took over this activity. Before the discovery of oil, Libya had very low economic promise, having been a major battle field during both World War I and II.



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

История изучения



Geological studies really started in 1926 when Ardito Desio was assigned by the Italian Geographic Society to explore the Giarabub (Al-Jaghbub), an oasis within the Libyan Sahara. Ardito Desio organized and led this geographical and geological expedition, resulting in the publication of four volumes on the local geology. From 1930 to 1933 Ardito Desio led geological and geographical expeditions into the hinterland of Libya. One of the most notable was in the summer of 1931 and sponsored by the Italian National Academy. It crossed the Sahara desert using a large caravan of camels from the Mediterranean to the frontier of Sudan and back across the Libyan Sahara through the Fezzan. The report of this expedition was published in 4 volumes.

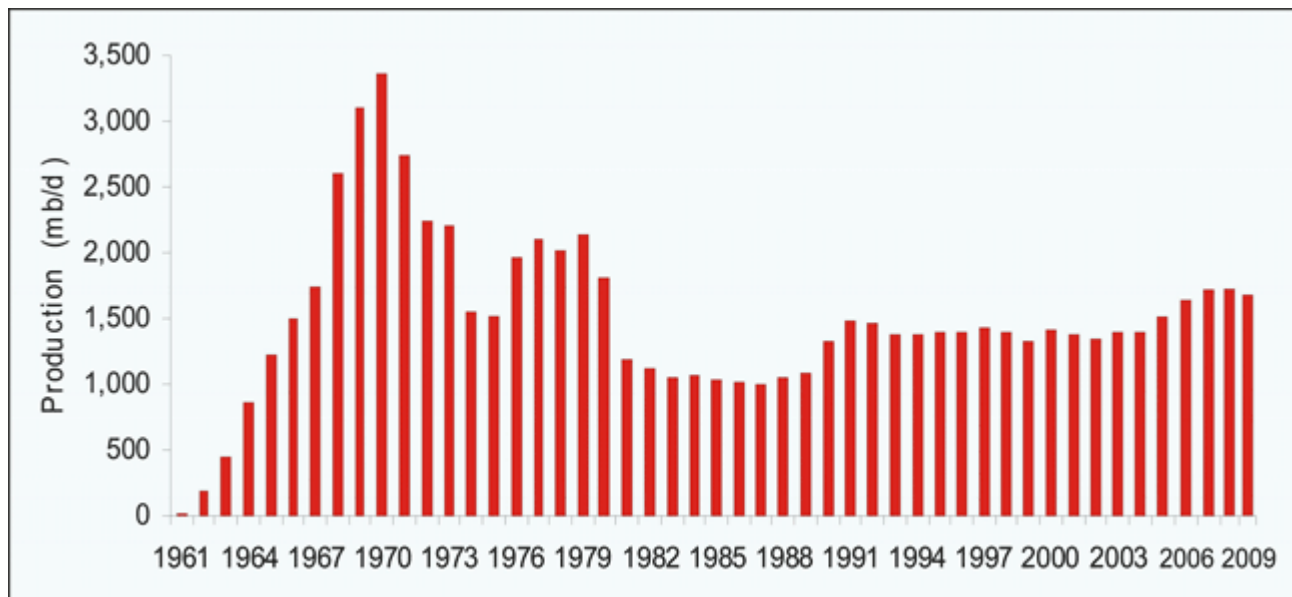
In 1930's, doubt was generated by geologists, who included Desio (1935), that Libya might have little in the way of commercial hydrocarbon accumulations. and coincidentally no oil discoveries were made under the Italian administration.

From 1954 to 1962 in search of water and minerals large areas of the country were photographed by the petroleum industry supplementing the information gleaned from the large portions that had been mapped by the Italians, British, American military personnel, and by the United States Geological Survey.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

История изучения

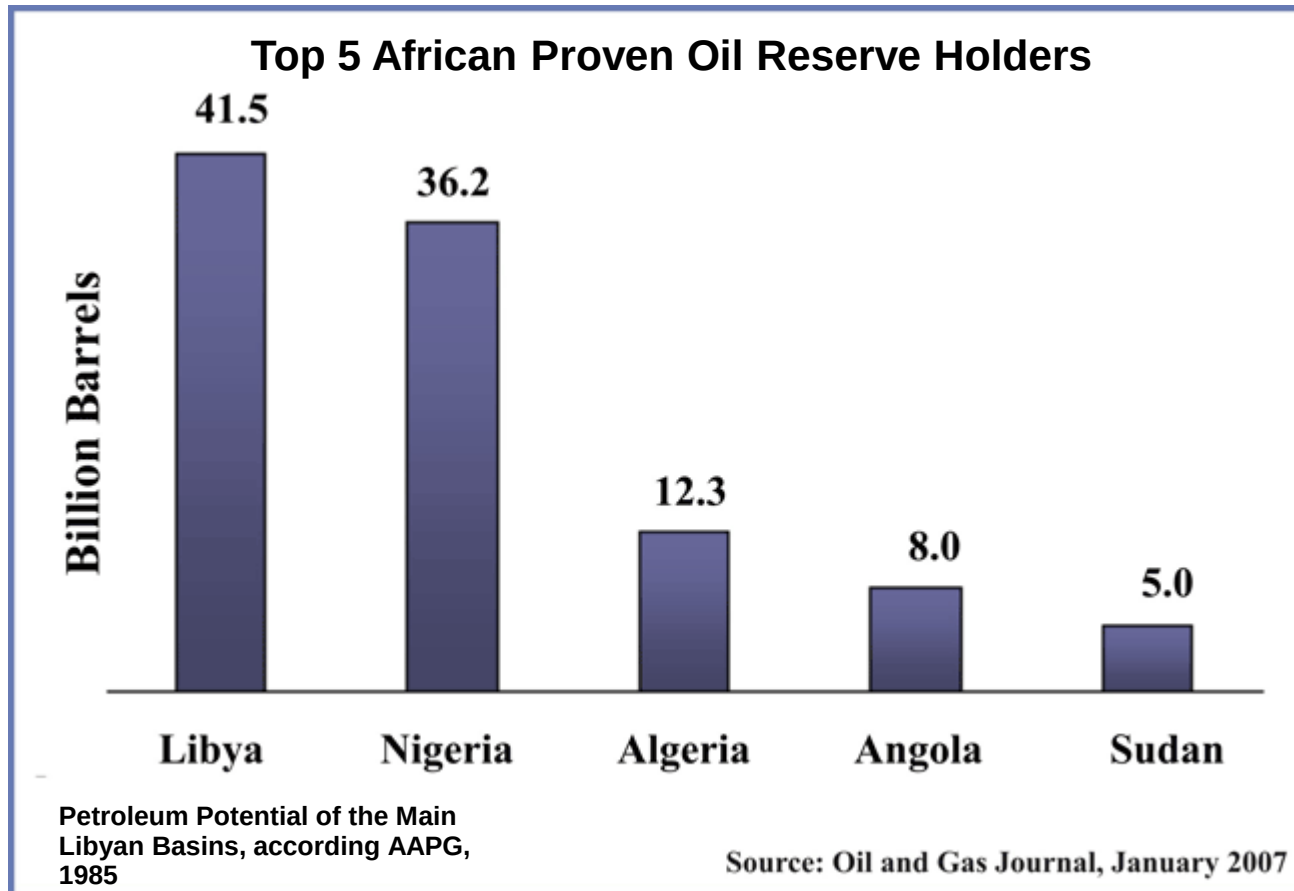
Active exploration in Libya started in 1953 after oil was discovered in neighboring Algeria. The first well was drilled in 1956 in western Fezzan, and the first oil was struck in 1957. In 1959, just as several companies were planning to release their exploration acreage, **Esso (now ExxonMobil)** made the first commercial discovery. The first oil flowed by pipeline from Esso's concession at Zaltan to its export facilities at Marsa al Burayqah in 1961. Other companies rushed to enter Libya, leading to additional discoveries. Forty two foreign companies conducted exploratory and drilling activities under concession contracts that covered an area of 600,000 km². In September 1961 production started, and by 1965, Libya was the world's sixth-largest exporter of oil. By the end of 1969, Libya's production reached 15.4% of OPEC's total and 7.5% of the world's total. In 1969 a major oil field was discovered at Sarir, which is well to the southeast of the Sirt Basin fields. Minor fields were discovered located in northwestern Tripolitania. New discoveries were drilled in the Ghadamis sedimentary basin (400 kilometers southwest of Tripoli) in 1974 and in the offshore fields 30 kilometers northwest of Tripoli in 1977.



Libyan oil production over the past 40 years

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

История изучения



Libya's National Oil Corporation (NOC) was established in 1968 and by 1973 had assumed control of exploration and development, production, refining, processing and marketing. While production-sharing agreements with foreign companies proliferated NOC, never the less, ended owning at least 51% of the exploration. By 2003 Libya was Opec's eighth largest producer. From 1993 to 2002, oil had been discovered in 136 wells out of the 270 drilled, a 50% success rate.

Ливия и Северная Африка

Table 1. North African petroleum reserves and their global significance

Rank	Country	Reserves (10 ⁹ BBO)
<i>Oil reserves (remaining)</i>		
1	Saudi Arabia	261.2
2	Iraq	100.0
3	United Arab Emirates	98.1
4	Kuwait	96.5
5	Iran	88.2
6	Venezuela	64.5
7	Mexico	49.8
8	Russia*	49.0
9	USA*	29.6
10	Libya	29.5 (2.9% of world total)
11	China	24.0
12	Nigeria	20.8
13	Algeria*	9.2 (0.9% of world total)
–	Egypt (inc. Gulf of Suez)	3.9 (0.4% of world total)
–	Tunisia	0.4 (<0.1% of world total)
Rank	Country	Reserves (10 ¹² SCF)
<i>Gas reserves (remaining)</i>		
1	Russia*	1700
2	Iran	742
3	Oman	250
4	United Arab Emirates	205
5	USA*	164
6	Venezuela	140
7	Algeria*	128 (2.6% of world total)
8	Nigeria	110
9	Iran	110
10	Indonesia	69
19	Libya	46 (0.9% of world total)
–	Egypt (inc. Gulf of Suez)	22 (0.4% of world total)

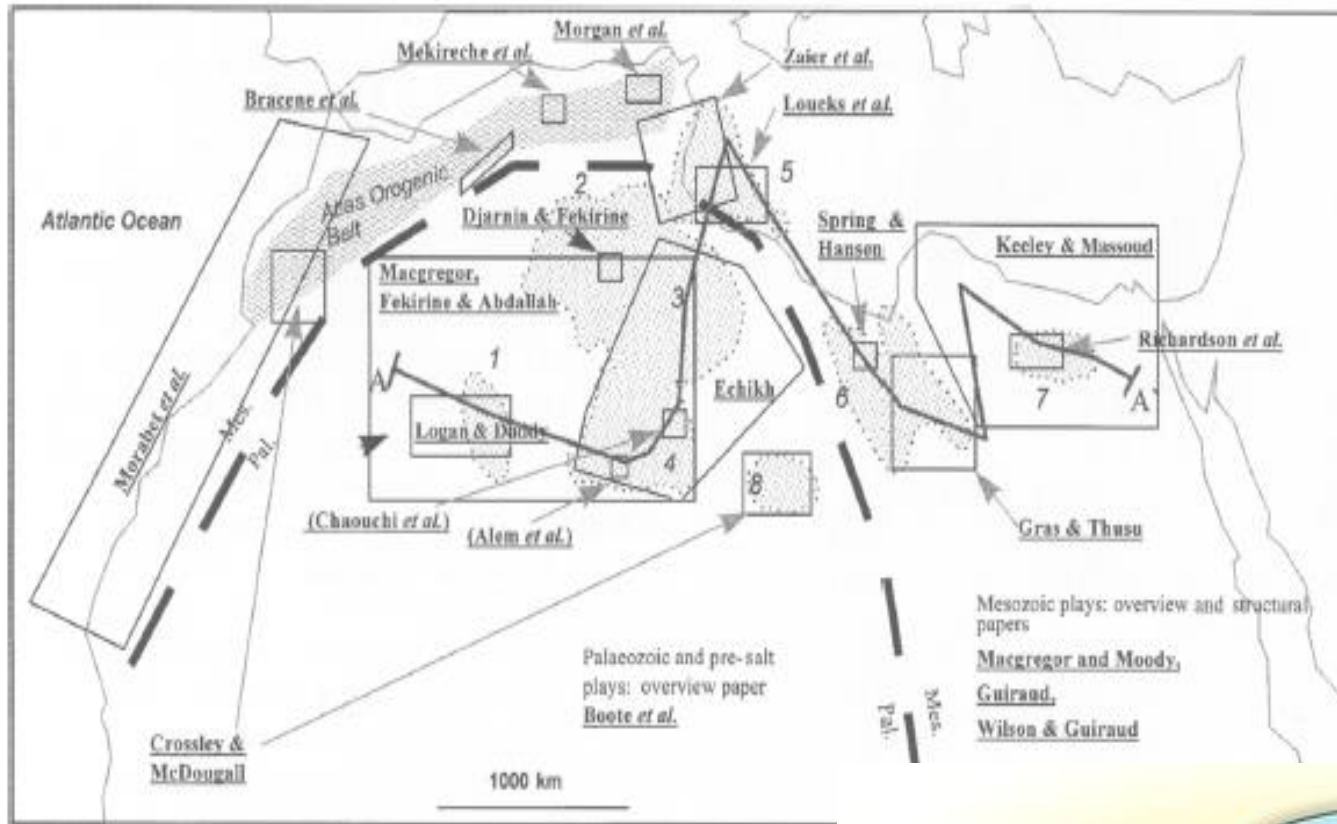
*Areas with significant Palaeozoic–Triassic reservoir component to reserves.

Source: BP Statistical Review of World Energy, 1996, data as at end 1995. BBO, Billion barrels of oil; SCF, standard cubic feet.



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Ливия и Северная Африка



The main petroleum basins are stippled and numbered as follows: 1, Ahnet; 2, Oued Mya; 3, Ghadames; 4, Illizi; 5, Gabes-Pelagian; 6, Sirt; 7, Abu Gharadiq; 8, Murzuq.

Onshore Sedimentary Basins of Libya

Sirt

Muruzq

Ghadamis

Cyrenaica

Al Kufura

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

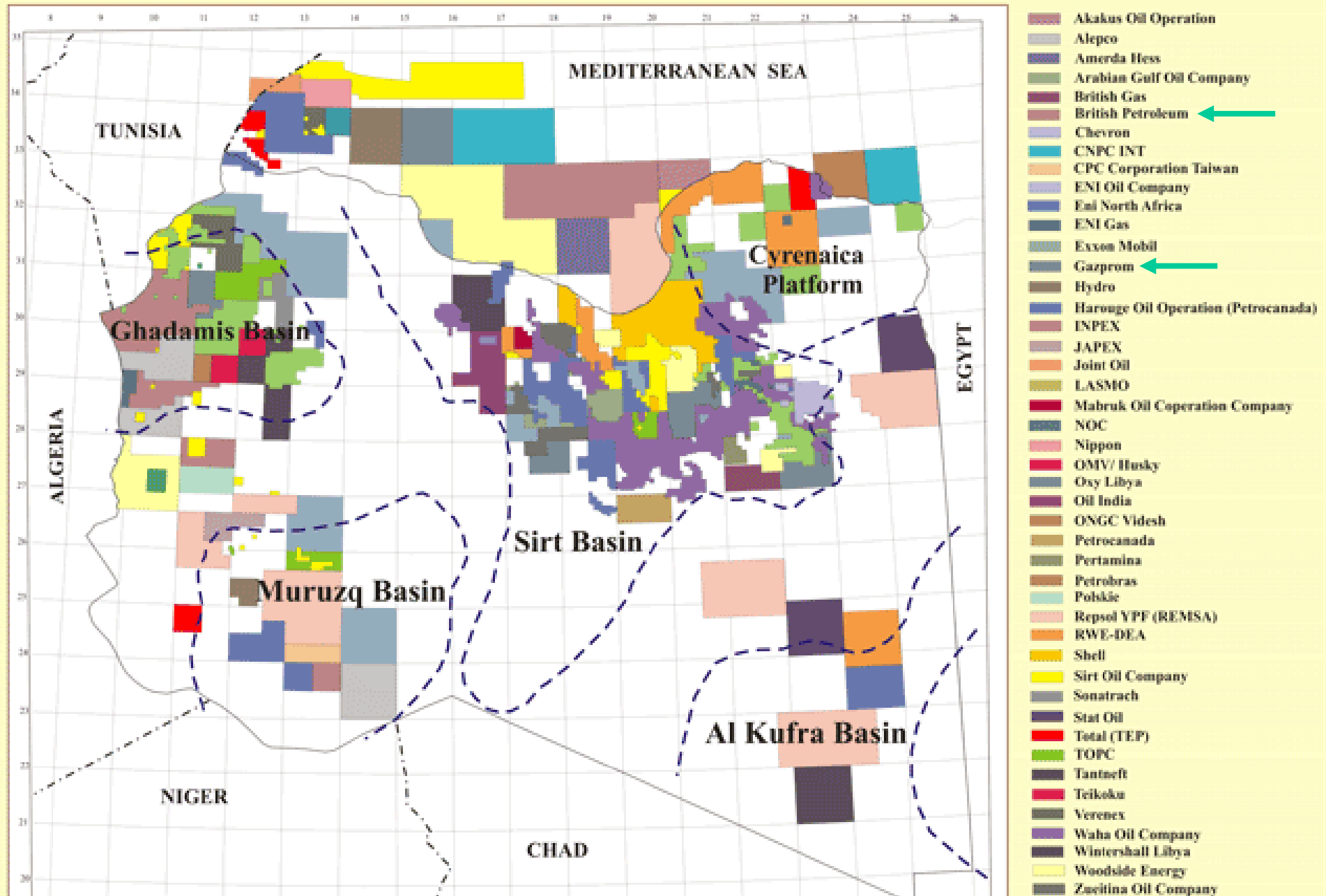
Ливия

Petroleum Basins	Ultimate Potential
Pelagian	Good/Excellent
Ghdames	Good/Excellent
Kufra	Poor/Fair
Muruzq	Fair
Cyrenaica	Fair/Good
Sirt	Excellent
Gulf of Sirt	Fair/Good

Petroleum Potential of the Main Libyan Basins, according AAPG, 1985

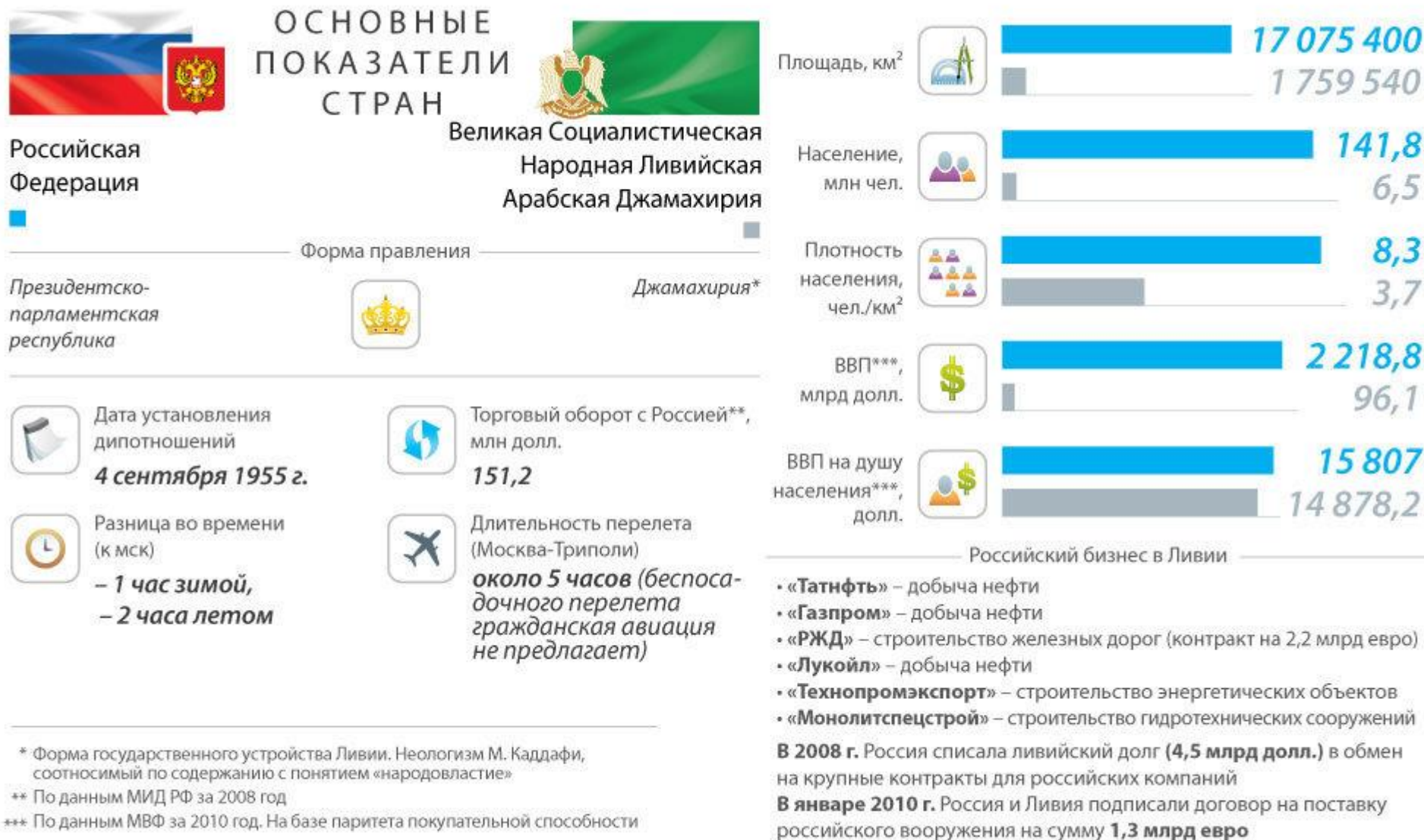
Source: AAPG, 1985

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Modified after NOC, 2007
Hassan S. Hassan (2009)

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии: НС Северной Африки



* Форма государственного устройства Ливии. Неологизм М. Каддафи, соотносимый по содержанию с понятием «народовластие»

** По данным МИД РФ за 2008 год

*** По данным МВФ за 2010 год. На базе паритета покупательной способности

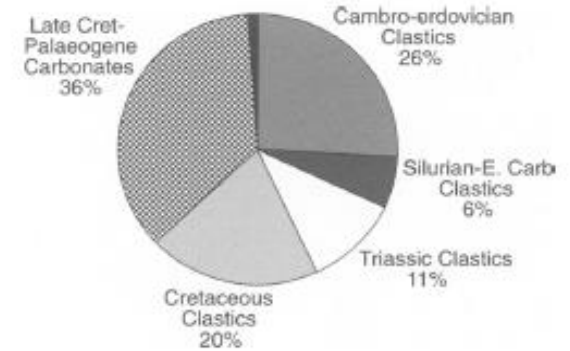
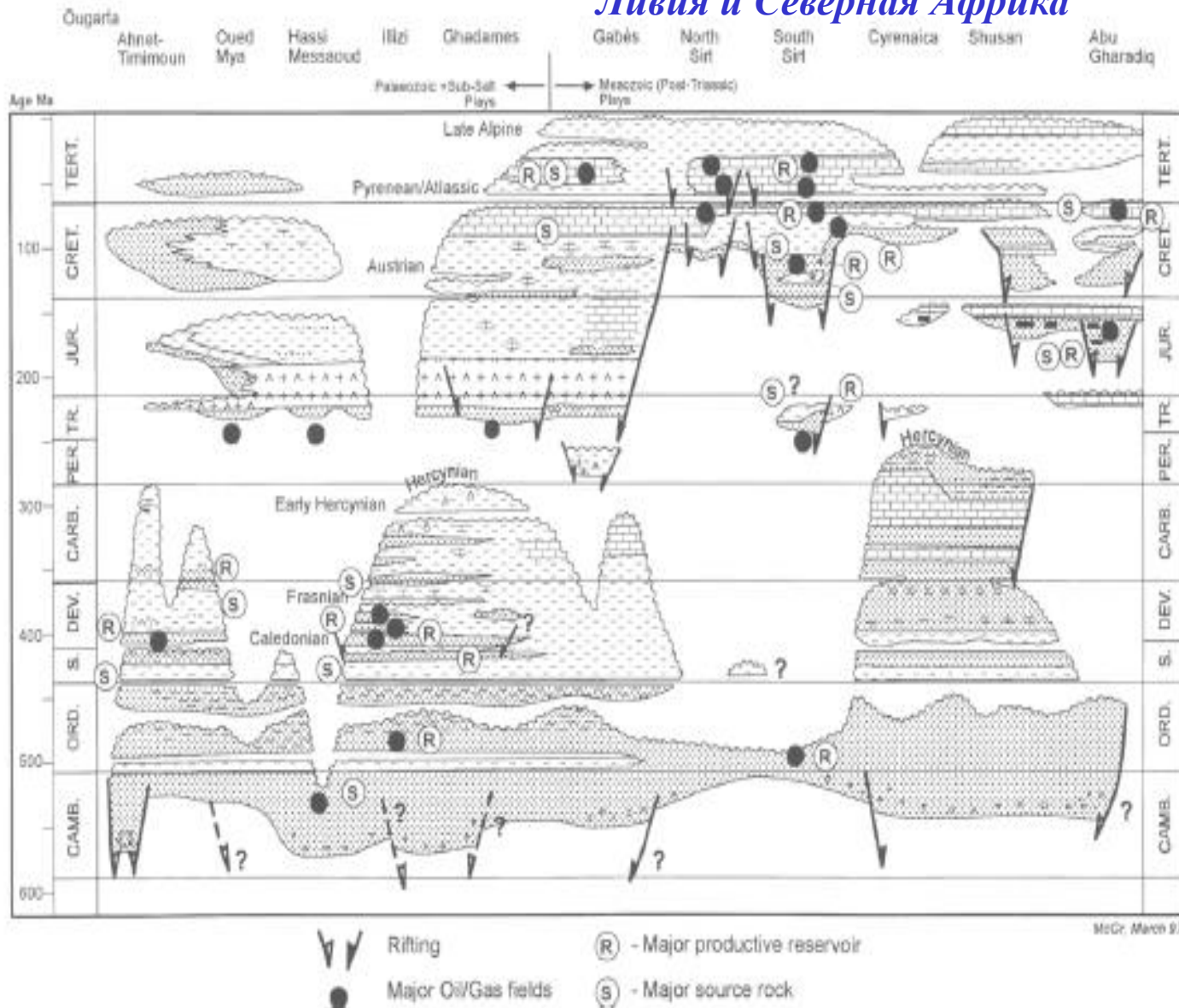
Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



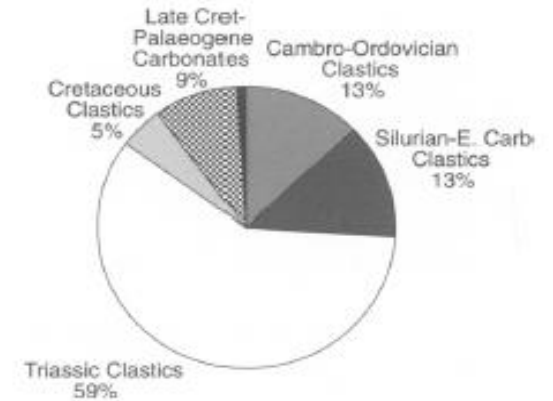
Libyan major oil pipelines, refiners and major oil fields. Source: National Oil Company, Energy Intelligence, Petroleum Economists

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Ливия и Северная Африка



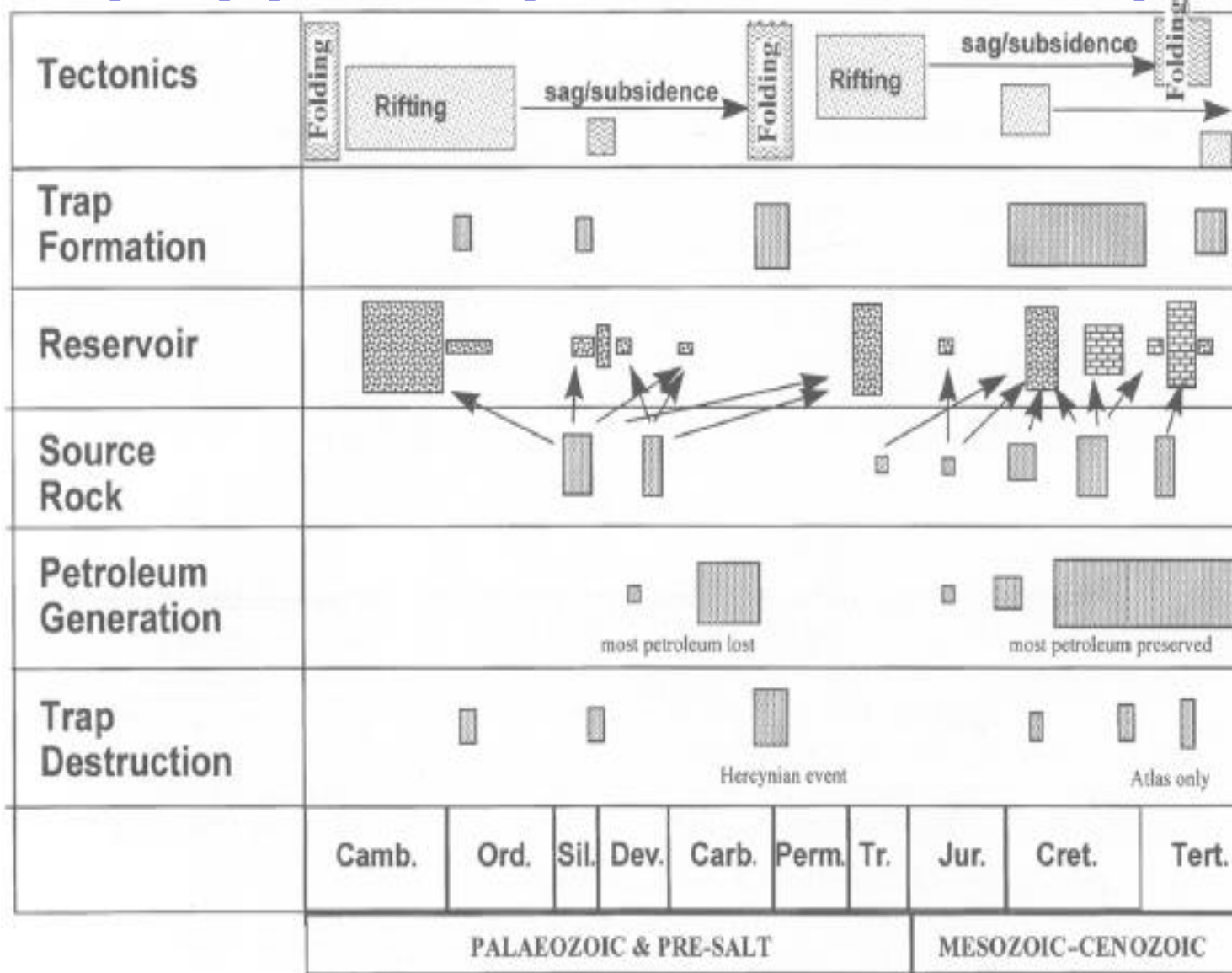
distribution of oil reserves



distribution of gas reserves

Chronostratigraphy of the Phanerozoic of the main North African petroleum provinces. The most significant oilfields, reservoirs and source rocks are labelled.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии: НС Северной Африки



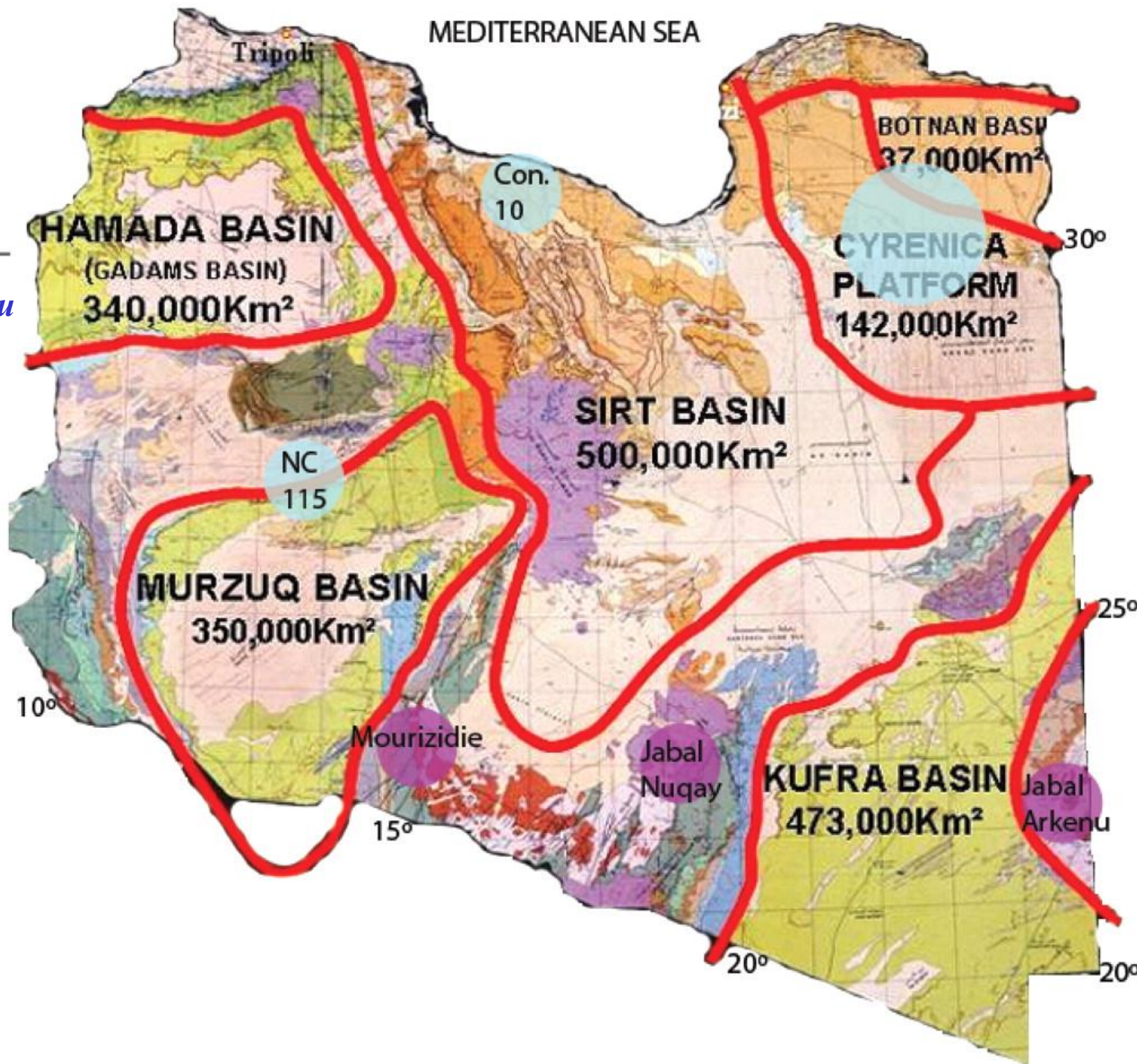
Composite petroleum system diagram for the North African provinces. The boxes are sized according to the relative importance of the various reservoirs, source rocks and events. It is possible to differentiate two main plate tectonic cycles, Cambrian to Carboniferous and Triassic to Recent, which are also reflected in cycles of petroleum generation, entrapment and destruction.

**Existing hydrocarbon-bearing traps only.*



200 km

Лекция 5.
Стратиграфия, НГБ и
нефтяные системы
Ливии: НС Северной
Африки



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии: НС Северной Африки



The Palaeozoic petroleum systems of North Africa contain five large giant (> 1 billion barrels of oil equivalent) and 24 giant (> 250 million barrels of oil equivalent) oil and gas fields with total recoverable reserves discovered to date of more than 46 billion barrels of oil equivalent.

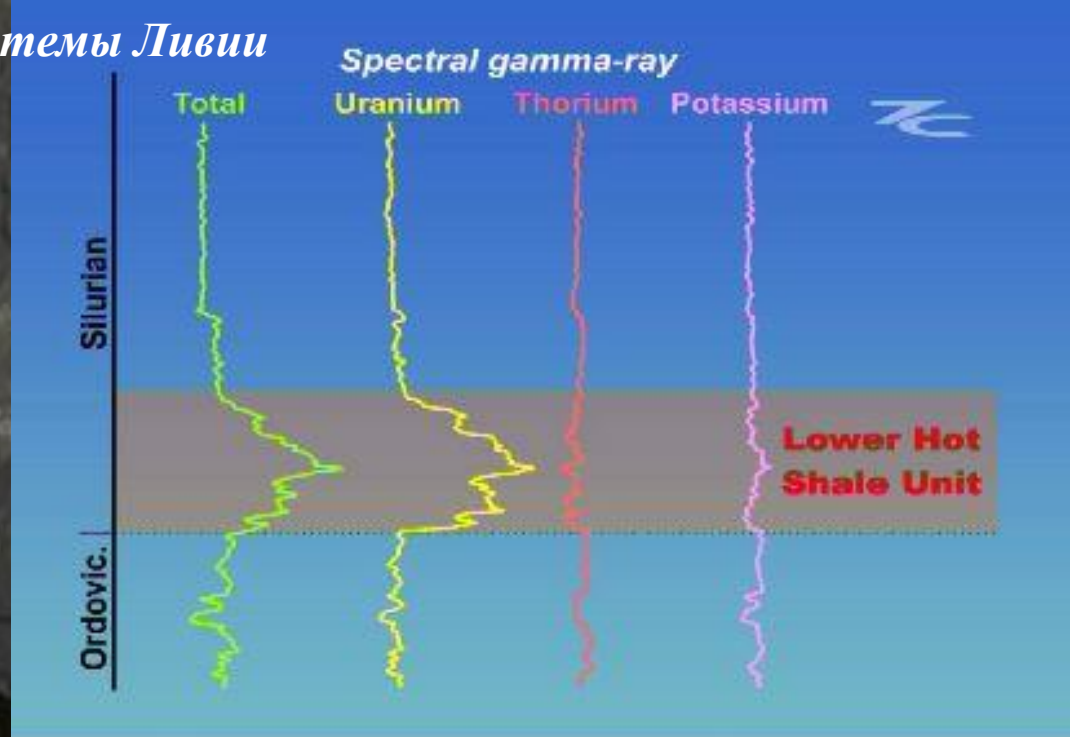
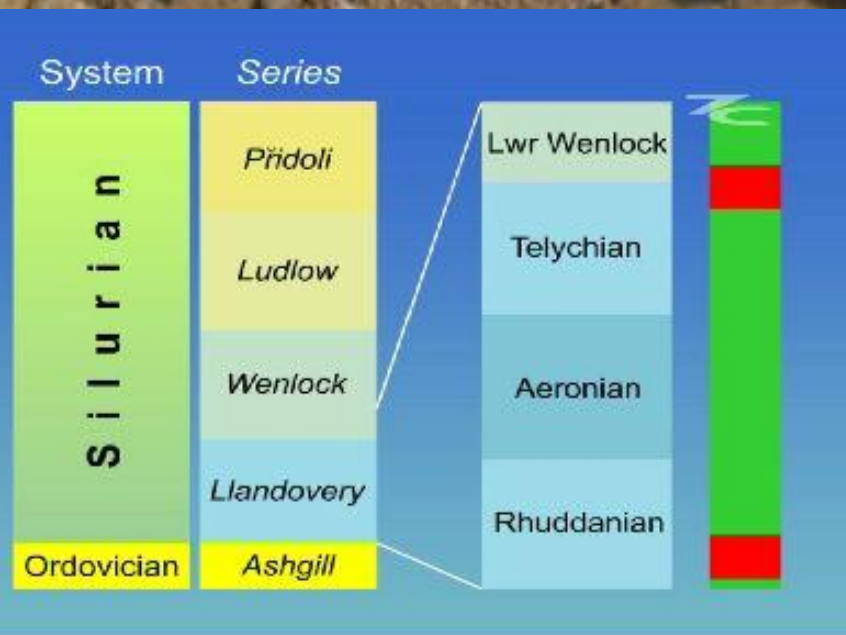
The regionally extensive Lower Silurian Tanezzuft Formation is the origin of 80-90% of Palaeozoic sourced hydrocarbons, with a further 10% from the Upper Devonian Frasnian shales, charging a number of intra-Palaeozoic and basal Triassic reservoirs. Triassic fluvial sands are the most important of these, hosting just over half of the total reserves, while Cambro-Ordovician and Lower Devonian F6 sandstone reservoirs are the second and third most significant, respectively.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

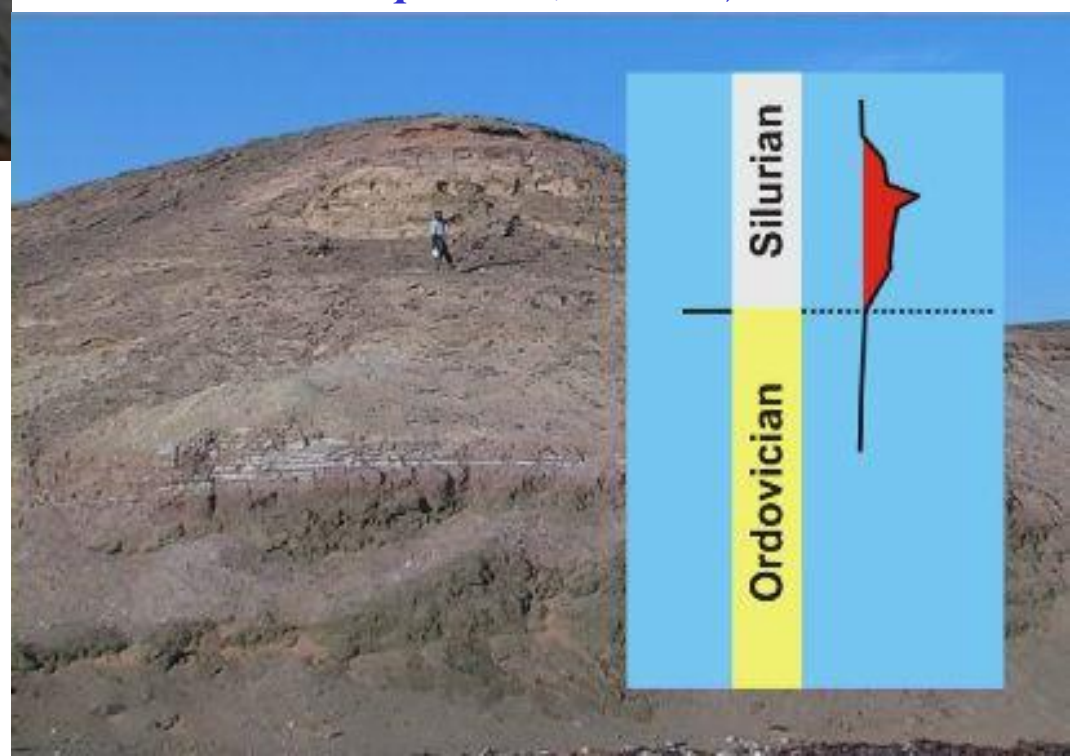
Нефтематеринские породы Северной Африки



The Silurian 'hot shales' are a key source rock in North Africa and Arabia



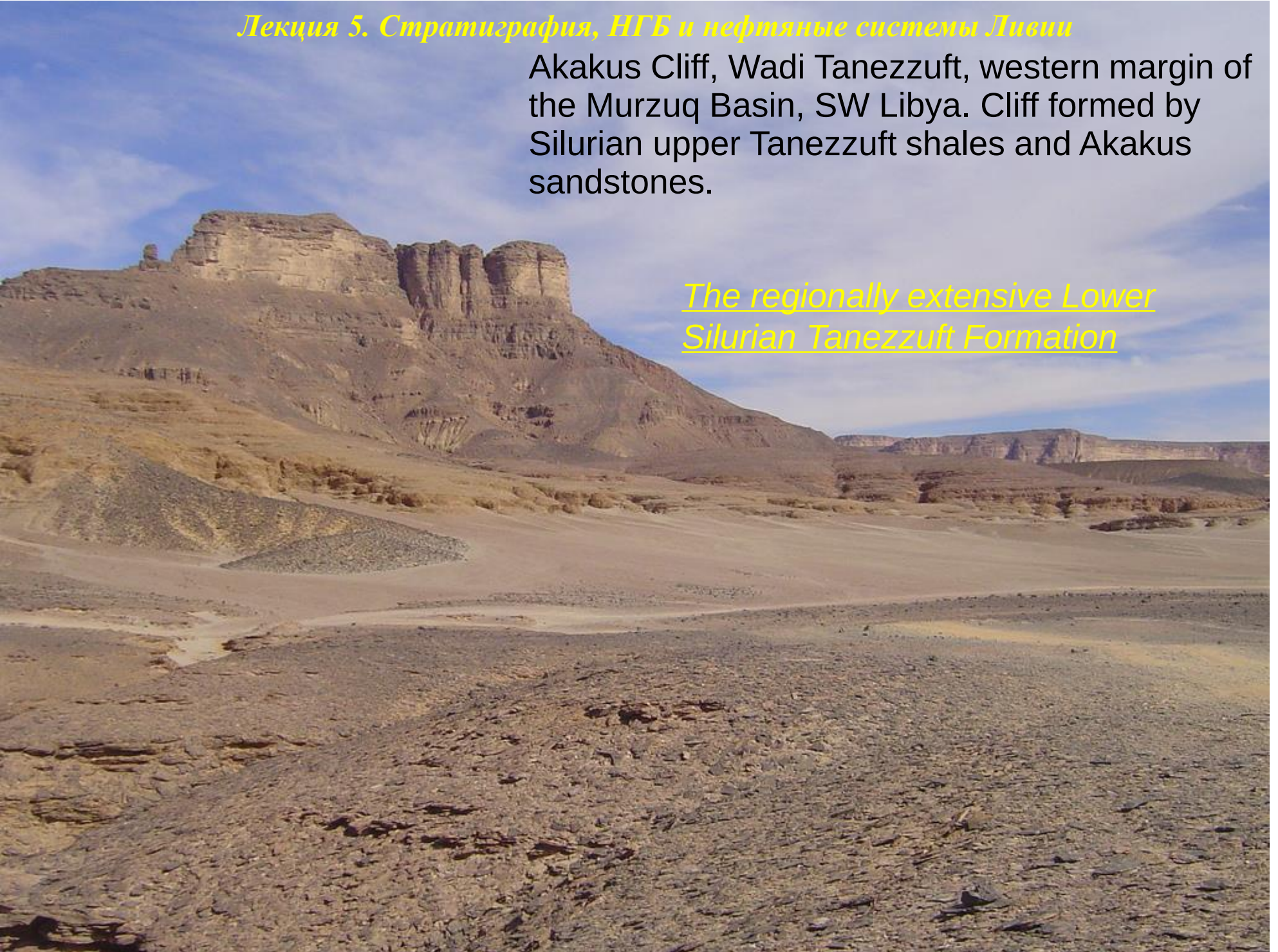
Региональный горизонт, обогащенный ОВ



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Akakus Cliff, Wadi Tanezzuft, western margin of the Murzuq Basin, SW Libya. Cliff formed by Silurian upper Tanezzuft shales and Akakus sandstones.

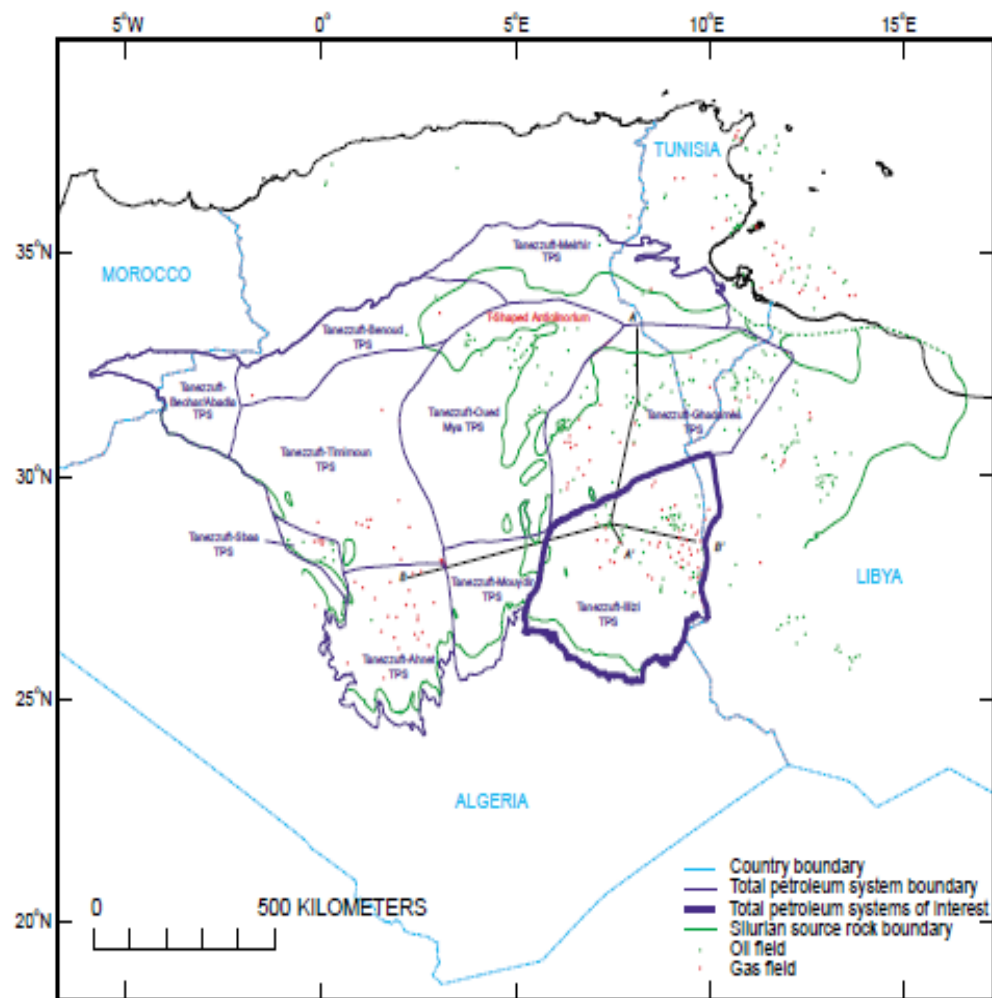
The regionally extensive Lower Silurian Tanezzuft Formation



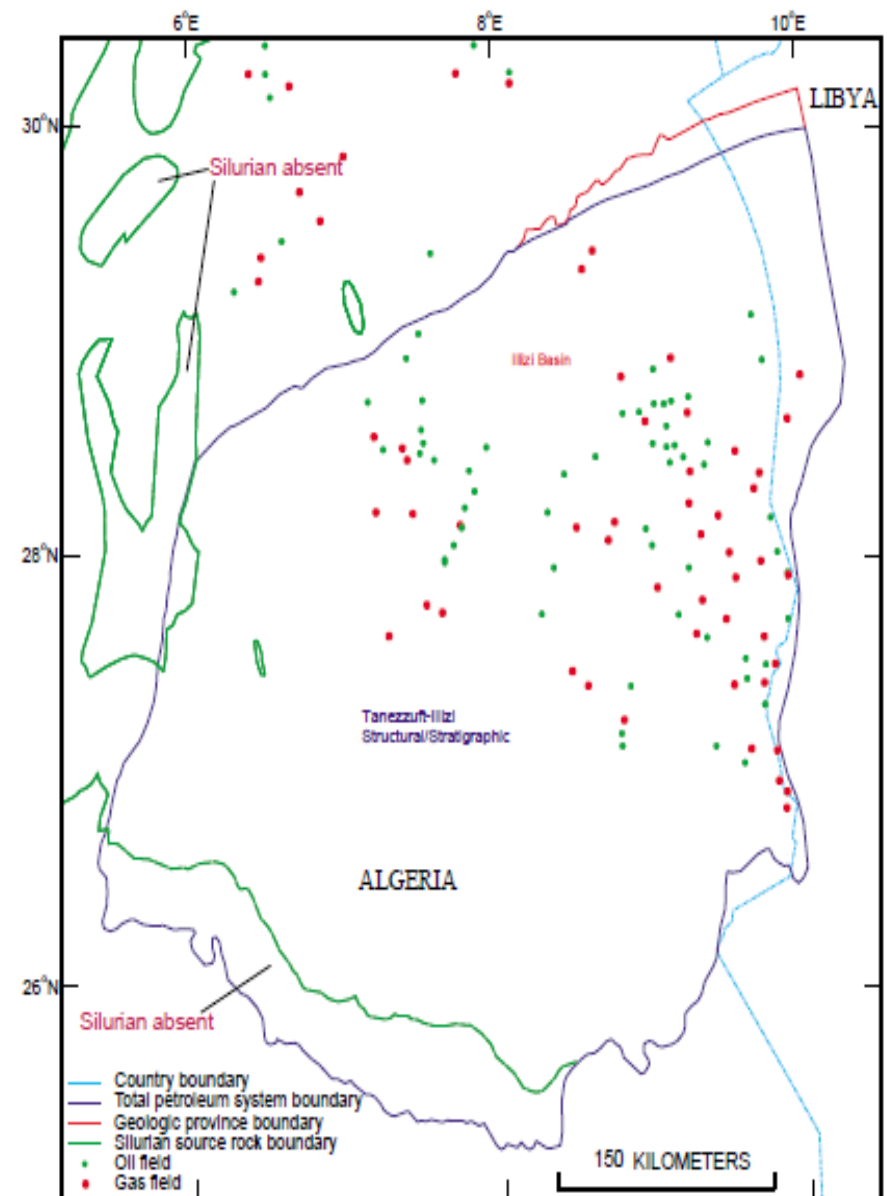


Tanezzuft warm shale bed with 11 ppm uranium in Jebel Eghei (western Kufra Basin margin, SE Libya).

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



North-central Africa, showing the areal extent of total petroleum systems and Silurian source rocks (Tanezzuft Formation), and locations of stratigraphic cross sections



Areal extent of assessment units within the Illizi Province

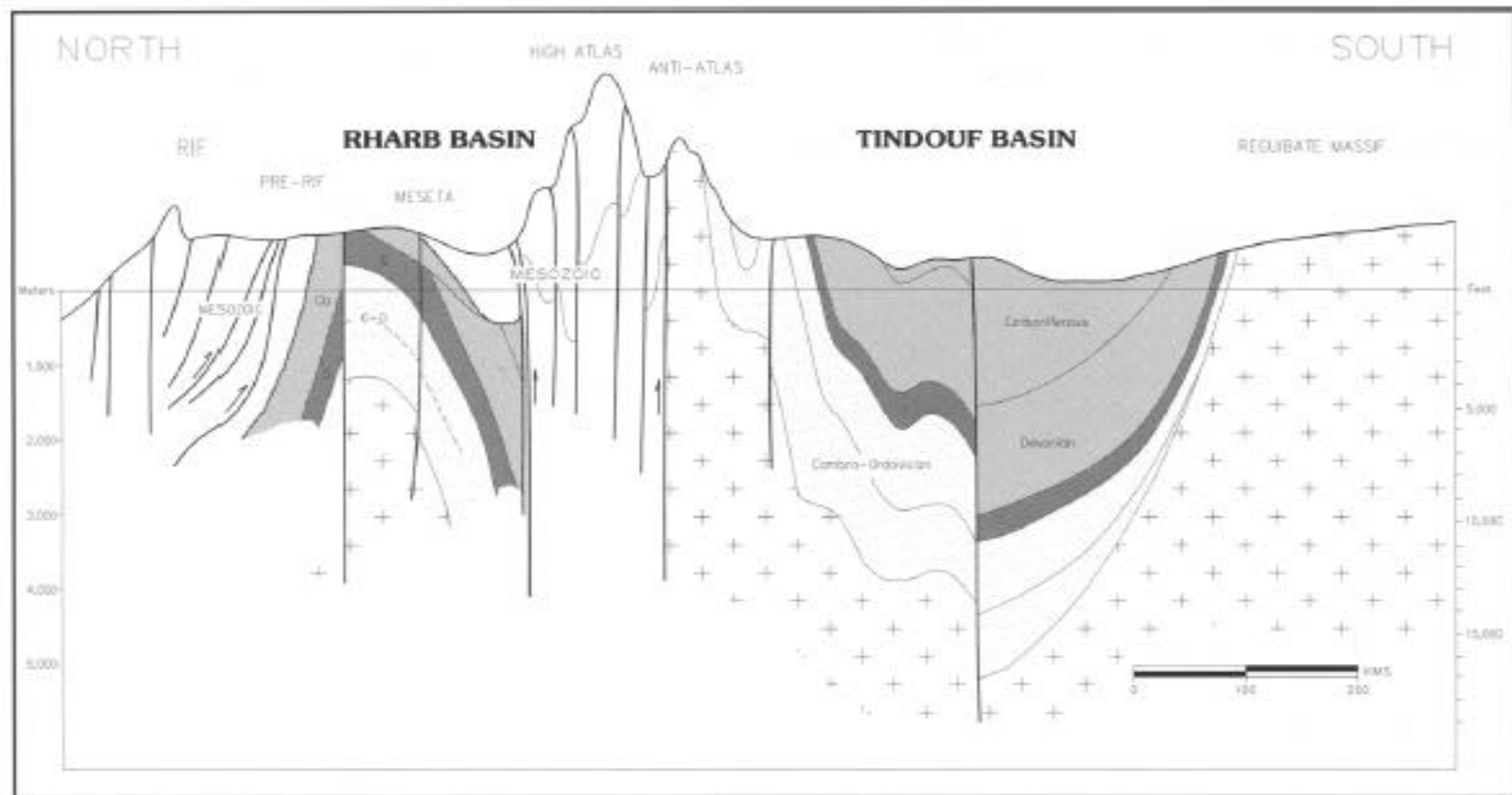
Three categories of Palaeozoic petroleum systems have been identified:

- (1) Mesozoic to early Tertiary charged systems with Triassic-Liassic shale and evaporite seals in the Mesozoic sag or 'Triassic' Basin of the northern Sahara Platform. These include > 78% of the total discovered reserves, with > 56% in the supergiants, Hassi R'Mel and Hassi Messaoud fields
- (2) Mesozoic to early Tertiary charged systems with intra-Palaeozoic shale seals in basins of south and east of the Triassic Basin. These include > 18% of the total discovered reserves, mostly in the prolific Illizi Basin.
- (3) Now largely extinct Palaeozoic charged systems with intra-Palaeozoic seals in basins of southwest Algeria and Morocco with 3% of discovered reserves.



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

The North African Platform lies yoked between the African Shield in the south, with its Eglab, Hoggar, Tibesti, Jebel Awaynat and Nubian Precambrian massifs, and the Atlassic-Maghrebian fold belts and East Mediterranean Basin in the north



Generalized structural cross-section across the Rharb and Tindouf Basins

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

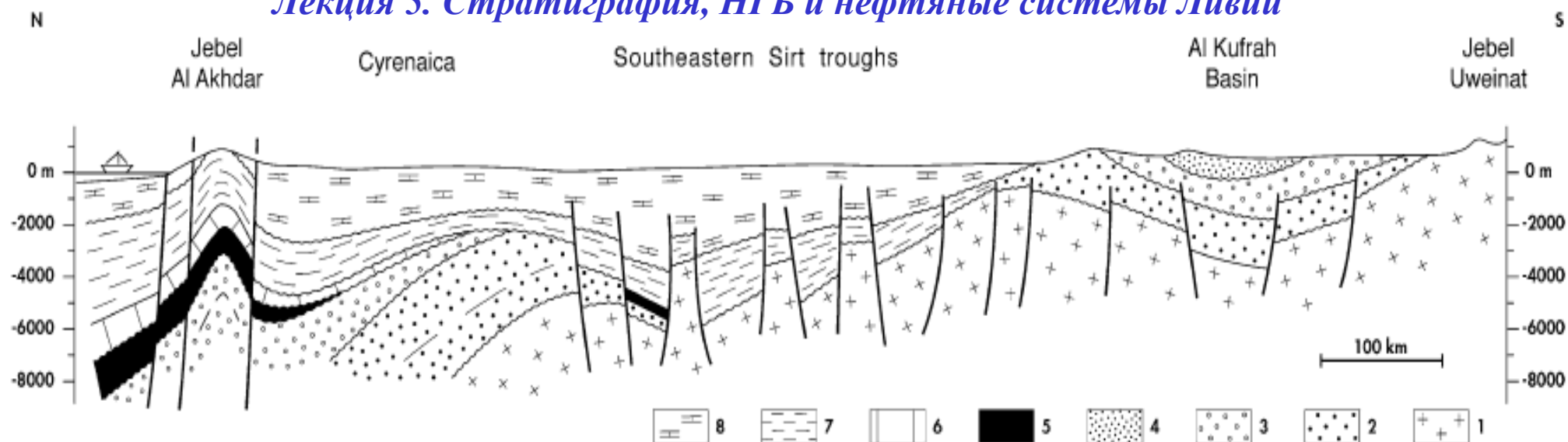


Fig. 7. Schematic geological cross-section along eastern Libya, after Guiraud and Bosworth (1999). Vertical exaggeration $\times 20$. (1) Pan-African basement; (2) Early Paleozoic; (3) Late Paleozoic; (4) undifferentiated Mesozoic; (5) Triassic; (6) Jurassic; (7) Cretaceous; (8) Cenozoic.

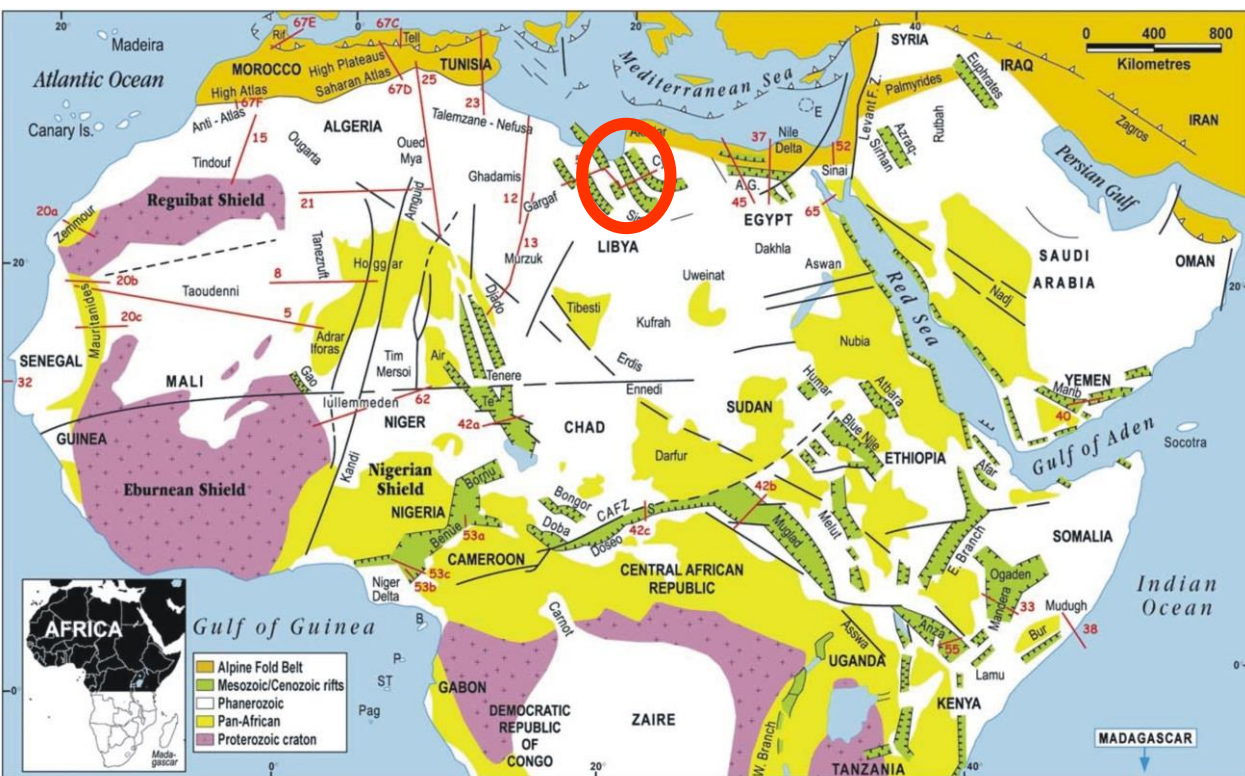
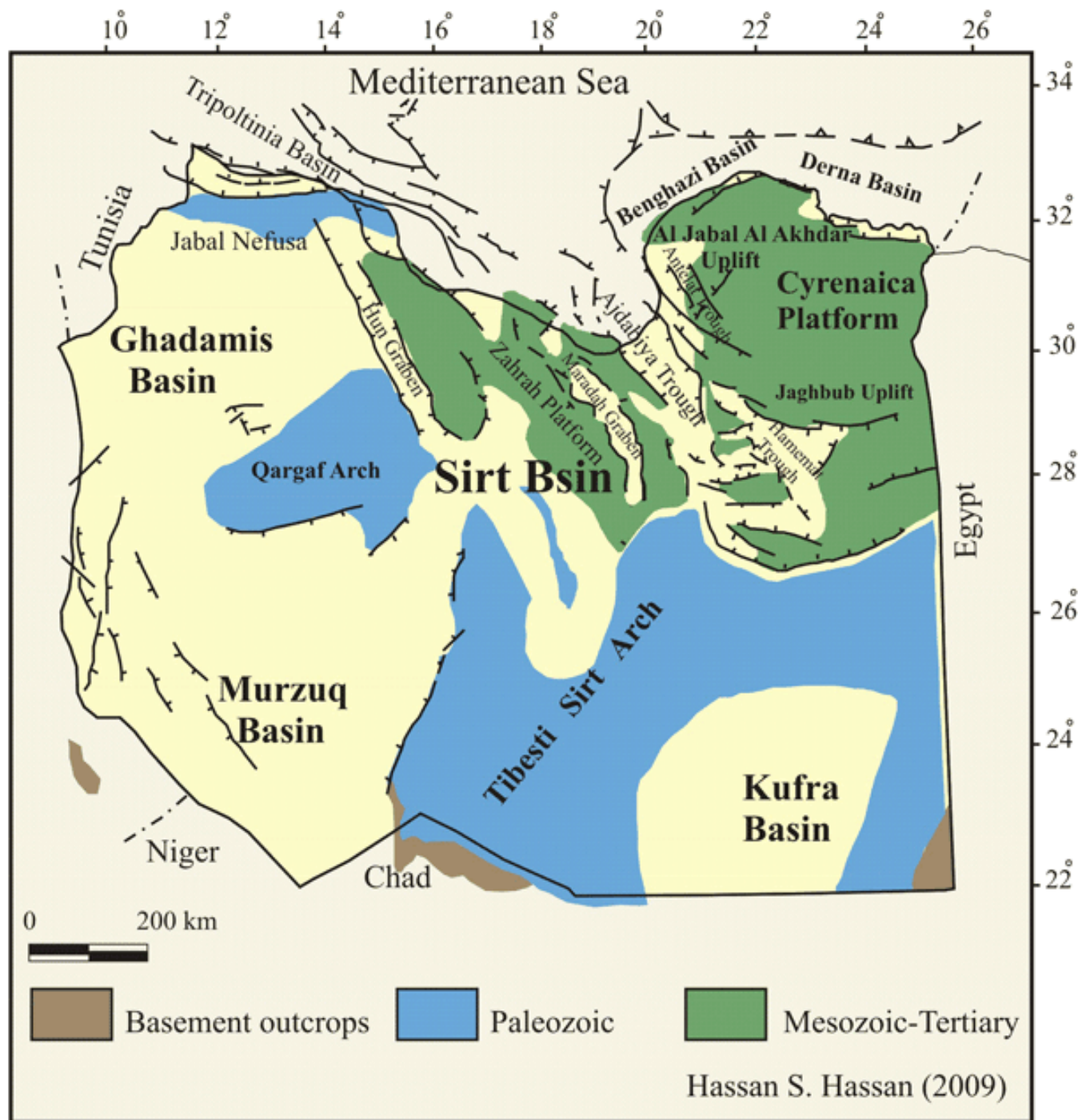


Fig. . Schematic geological map of Northern Africa, Central Africa and Arabia

Legend: AG, Abu Gharadig; B, Bioko; CAFZ, Central African Fault Zone; Cyr, Cyrenaica; E, Eratosthenes Seamount; JP, Jos Plateau; P, Principe; Pag, Pagalu; S, Salamat; ST, Saomé; Te, Termit.

The underlying Precambrian basement evolved as part of Pangaea, formed from the collision and suturing of several cratons and intervening island arcs during the Pan-African orogeny. This subsequently evolved into a stable Gondwana and later Tethyan passive continental margin, interrupted by Hercynian deformation in the late Carboniferous, rifting during the Mesozoic and Alassic-Maghrebian orogenesis in mid-late Tertiary. A widespread Hercynian unconformity divides the sedimentary cover into a lower Gondwana Super-Cycle of mildly deformed Palaeozoic clastic deposits and an upper Tethyan Super-Cycle of Mesozoic-Tertiary clastic deposits, evaporites and carbonates.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

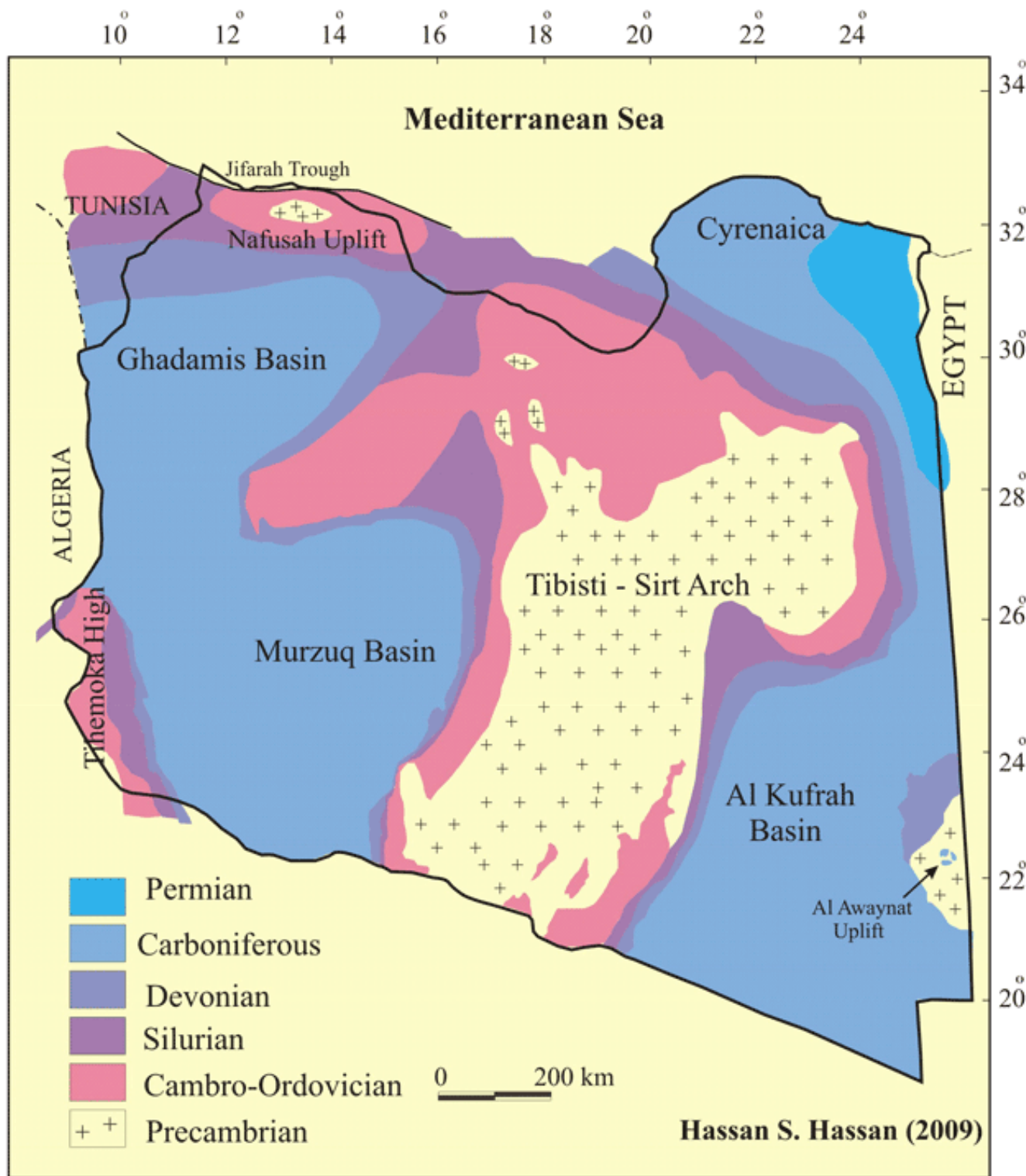




Mesozoic continental Nubian Sandstones, Jebel Bin Genihma, eastern margin of the Murzuq Basin, SW Libya ([collector](#))

Paleocene-Eocene carbonates (**collector**) north of Dor El Gusa, eastern margin of the Murzuq Basin, SW Libya. Note small volcanic pipe





Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



upper Devonian Awaynat Wanin Fm



Ordovician Hawaz Formation in Jebel Eghei, western margin of the Kufra Basin, SE Libya.

Period	Age	Ma	NW Libya	SW Libya	SE Libya	NE Libya	W Egypt
			Ghadamis Basin	Muruzq Basin	Al Kufrah Basin	Cyrenaica	Western Sahara
Permian	Permian					Bir Hacheim	Permian
Carboniferous	Gzhelian	299	Tiguentourine Fm.			Tig Fm.	Safi
	Moscovian	311.7	Dembaba	Dembaba	Dalma	Dembaba Equiv.	Dhiffah
	Bashkirian	318.1	Assedjefar	Assedjefar		Assedjefar Equiv.	
	Serpukhovian	326.4					
	Visean	345.3	Collenia beds	Collenia beds			
	Tournaisian	359.2	M'rar	M'rar			
Devonian	Famennian	374.5			Benim		Desouqy
	Fransnian	385.3	Wadi Ash Shati	Awaynat Wanin		Awaynat Wanin Equivalent	
	Givetian	391.8	Awaynat Wanin				Zaitoun
	Eifelian	397.5			Tadrat		
	Emsian	407.0	Quan Qasa Tadrat	Quan Qasa Tadrat		Quan Qasa	
	Pargian	411.2					
	Lochkovian	416.0					
Silurian	Pridoli	418.7	Acacaus	Acacaus	Acacaus		
	Ludlow	422.9				Acacaus Equiv.	Basur
	Wenlock	428.2	Tanezzuft	Tanezzuft	Tanezzuft	Tanezzuft Equival.	Kohla
	Llandovery	443.7					
Ordovician	Hirnatian	445.6	Memouniat	Memouniat		Memouniat Equ.	
	Katian	455.1	Melez Chograne	Melez Chograne		Melez Chograne Equiv.	
	Sandbian	460.9					
	Darriwilian	468.1	Haouaz	Haouaz			Shafah
	Floian	471.8		Ash Shabiyat			
	Tremadocian	488.3					
Cambrian	Upper	499.0	Hasawanah	Hasawanah	Hasawanah		
	Middle	510.0					
	Lower	521.0					
Precambrian			Infra-cambrian	Mour-izidie	Infra-cambrian		

 Hydrocarbon source
  Reservoir rocks (Modified after Craig et al., 2006)

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Asterophyton fabrics in sandstones underlying the Tanezzuft "warm shale"



Silurian Cruziana - trilobite traces - Akakus Formation, northern Jabal Asba

Precambrian marble, Jebel Babein, eastern margin of the Kufra Basin, SE Libya



Period	Age	Ma			NW Libya	SW Libya	SE Libya
					Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian						
Carboniferous	Gzhelian	299	Tiguentourine Fm.				
	Moscovian	311.7	Dembaba	Dembaba			
	Ilashkirian	318.1	Assedjefar	Assedjefar			
	Serpukhovian	326.4					Dalma
	Viscun	345.3	Collana beds	Collana beds			
	Tournaisian	359.2	M'rar	M'rar			
Devonian	Famennian	374.5	Wadi Ash Shari				
	Frasnian	385.3	Awaynat Wanin	Awaynat Wanin			Benim
	Givetian	391.8					
	Eifelian	397.5					
	Emasian	407.0	Quan Qasa Tadrat	Quan Qasa Tadrat			Tadrat
	Pargian	411.2					
	Lochkovian	416.0					
Silurian	Pridoli	418.7	Acacaus	Acacaus			Acacaus
	Ludlow	422.9					
	Wenlock	428.2	Tanezzuft	Tanezzuft			Tanezzuft
	Llandovery	443.7					
Ordovician	Hemian	445.6	Memouniat	Memouniat			
	Katian	455.3	Melex Cheganez	Melex Cheganez			
	Sarabum	460.9					
	Darriwilian	468.3	Haouaz	Haouaz			
	Floian	471.8					
Cambrian	Tremadocian	488.3		Ash Shubiyat			
	Upper	499.0	Hasawanah	Hasawanah			Hasawanah
	Middle	510.0					
Precambrian	Lower	521.0					

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Cambrian Hassauna sandstones. Jebel Eghei (western Kufra Basin margin, SE Libya).

Period	Age	Ma			NW Libya	SW Libya	SE Libya
					Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian						
Carboniferous	Gzhelian 299				Tiguentourine Fm.		
	Moscovian 311.7				Dembaba	Dembaba	
	Ilashkirian 318.1				Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4						
	Visean 345.3				Collenia beds	Collenia beds	
	Tournaisian 359.2				M'rar	M'rar	
Devonian	Famennian 374.5				Wadi Ash Shait		
	Frasnian 385.3				Awaynat	Awaynat	Benim
	Givetian 391.8				Wamin	Wamin	
	Eifelian 397.5						
	Emasian 407.0				Qian Qian	Qian Qian	Tadrat
	Pargian 411.2				Tadrat	Tadrat	
	Lochkovian 416.0						
Silurian	Pridoli 418.7				Acacaus	Acacaus	Acacaus
	Ludlow 422.9						
	Wenlock 428.2				Tanezzuft	Tanezzuft	Tanezzuft
	Llandovery 443.7						
Ordovician	Hemian 445.6				Memouniat	Memouniat	
	Katian 455.1				Meloz Cheganez	Meloz Cheganez	
	Sandbian 460.9						
	Darriwilian 468.1				Haouaz	Haouaz	
	Floian 471.8						
	Tremadocian 488.3					Ash Shubtyat	
Cambrian	Upper 499.0				Hasawana	Hasawana	Hasawana
	Middle 510.0						
	Lower 521.0						
Pre-Cambrian							

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Upper Cambrian Hasawnah Formation, south of Ghat, El Barkat, Murzuq Basin, SW Libya

Period	Age	Ma		
		NW Libya	SW Libya	SE Libya
		Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian			
Carboniferous	Gzhelian 299	Tiguentourine Fm.		
	Moscovian 311.7	Dembaba	Dembaba	
	Ilshkirian 318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4			
	Viscun 345.3	Collana beds	Collana beds	
	Tournaisian 359.2	M'rar	M'rar	
Devonian	Famennian 374.5	Wadi Ash Shan		
	Frasnian 385.3		Awaynat Wanin	Benim
	Givetian 391.8	Awaynat Wanin		
	Eifelian 397.5			
	Emasian 407.0	Quan Qasa Tadrat	Quan Qasa Tadrat	Tadrat
	Pargian 411.2			
	Lochkovian 416.0			
Silurian	Pridoli 418.7	Acacaus	Acacaus	Acacaus
	Ludlow 422.9			
	Wenlock 428.2	Tanezzuft	Tanezzuft	Tanezzuft
	Llandovery 443.7			
Ordovician	Hemian 445.6	Memouniat	Memouniat	
	Katian 455.3	Melex Chegrane	Melex Chegrane	
	Sarabun 460.9			
	Darriwilian 468.3	Haouaz	Haouaz	
	Floian 471.8			
Cambrian	Tremadocian 488.3			
	Upper 499.0	Hasawnah	Hasawnah	Hasawnah
	Middle 510.0			
Precambrian	Lower 521.0			

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

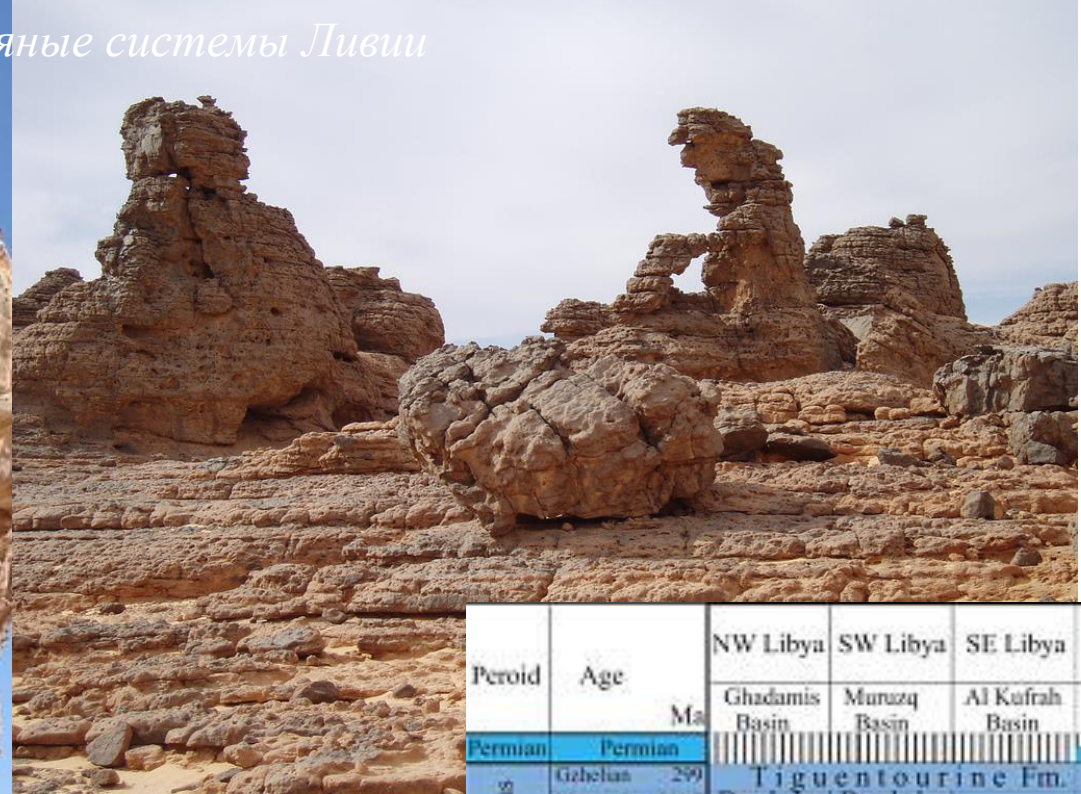


Tabular crossbeds, tidal bars, Lower Ashebyat ("Hawaz"), lower to mid Ordovician, south of Ghat, Murzuq Basin, SW Libya

Period	Age	NW Libya	SW Libya	SE Libya
	Ma	Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian			
Carboniferous	Gzhelian 299	Tiguentourine Fm.		
	Moscovian 311.7	Dembaba	Dembaba	
	Ilshkirian 318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4			
	Viscun 345.3	Collana beds	Collana beds	
	Tournaisian 359.2	M'rar	M'rar	
Devonian	Famennian 374.5	Wadi Ash Shari		
	Frasnian 385.3		Awaynat Wanin	Benim
	Givetian 391.8	Awaynat Wanin		
	Eifelian 397.5			
	Emasian 407.0	Quan Qasa	Quan Qasa	
	Pargian 411.2	Tadrat	Tadrat	Tadrat
	Lochkovian 416.0			
Silurian	Pridoli 418.7	Acacaus	Acacaus	Acacaus
	Ludlow 422.9			
	Wenlock 428.2	Tanezzuft	Tanezzuft	Tanezzuft
	Llandovery 443.7			
Ordovician	Hemian 445.6	Memouniat	Memouniat	
	Katian 455.3	Melex Chegane Melex Chegane	Melex Chegane Melex Chegane	
	Sandban 460.9			
	Darriwilian 468.3	Haouaz	Haouaz	
	Floian 471.8			
	Tremadocian 488.3			
Cambrian	Upper 499.0	Hasawannah	Hasawannah	Hasawannah
	Middle 510.0			
	Lower 521.0			
Precambrian				



Probably Mamuniyat glacial sandstones, upper Ordovician, central Jebel Asba, eastern margin of the Kufra Basin, SE Libya



Erosional sandstone pillars, Upper Ordovician glacial Mamuniyat Formation, north of Ghat, Murzuq Basin, SW Libya

Period	Age	NW Libya	SW Libya	SE Libya
	Ma	Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian			
Carboniferous	Gzhelian 299	Tiguentourine Fm.		
	Moscovian 311.7	Dembaba	Dembaba	
	Ilashkirian 318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4			
	Viscun 345.3	Collana beds	Collana beds	
	Tournaisian 359.2	M'rar	M'rar	
Devonian	Famennian 374.5	Wadi Ash Shari		
	Frasnian 385.3	Awaynat Wanin	Awaynat Wanin	Benim
	Givetian 391.8			
	Eifelian 397.5			
	Emasian 407.0	Quan Qasa Tadrat	Quan Qasa Tadrat	Tadrat
	Pargian 411.2			
	Lochkovian 416.0			
Silurian	Pridoli 418.7	Acacaus	Acacaus	Acacaus
	Ludlow 422.9			
	Wenlock 428.2			
	Llandovery 443.7	Tanezzuft	Tanezzuft	Tanezzuft
Ordovician	Hemian 445.6	Memsouat	Memsouat	
	Katian 455.3	Melex Chegrat	Melex Chegrat	
	Sandbian 460.9			
	Darriwilian 468.3	Haouaz	Haouaz	
	Floian 471.8			
	Tremadocian 488.3		Ash Shubiyat	
Cambrian	Upper 499.0	Hasawannah	Hasawannah	Hasawannah
	Middle 510.0			
	Lower 521.0			
Precambrian				

Glacial, channelised Mamuniyat Sandstone (glacial upper Ordovician) at Ghat Castle, Ghat, Murzuq Basin, SW Libya





Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

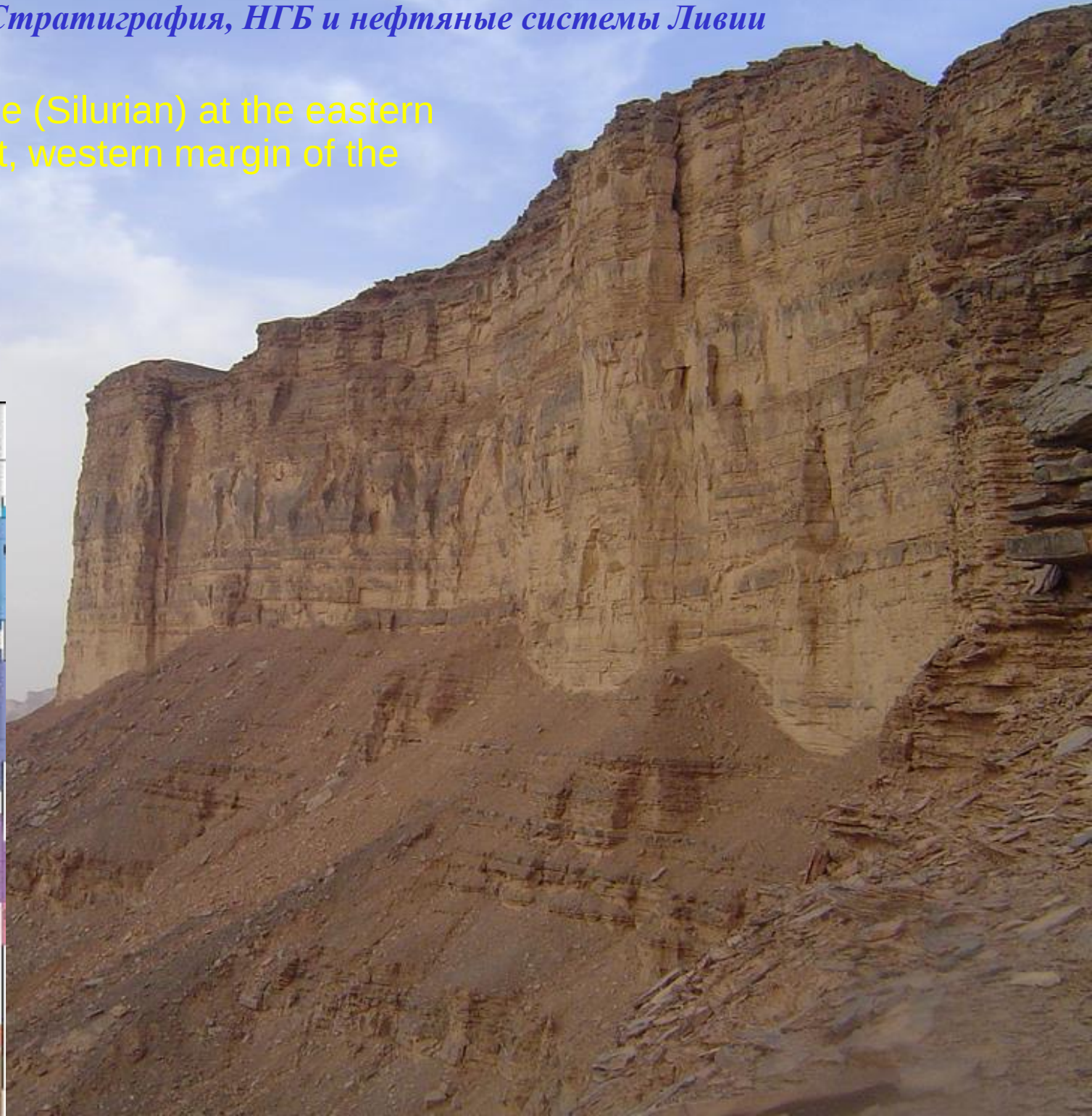
Glacially deformed Ordovician Mamuniyat in Jebel Eghei (western margin of the Kufra Basin, SE Libya).

Period	Age	Ma	NW Libya	SW Libya	SE Libya
			Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian				
Carboniferous	Gzhelian	299	Tiguentourine Fm.		
	Moscovian	311.7	Dembaba	Dembaba	
	Ilashkirian	318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian	326.4			
	Viscun	345.3	Collana beds	Collana beds	
	Tournaisian	359.2	M'rar	M'rar	
Devonian	Famennian	374.5	Wadi Ash Shati		
	Frasnian	385.3		Awaynat	Benim
	Givetian	391.8	Awaynat	Wanin	
	Eifelian	397.9	Wanin		
	Emasian	407.0	Qian Qian	Qian Qian	Tadrat
	Pargian	411.2	Tadrat	Tadrat	
	Lochkovian	416.0			
Silurian	Pridoli	418.7	Acacaus	Acacaus	Acacaus
	Ludlow	422.9			
	Wenlock	428.2			
	Llandovery	443.7	Tanezzuft	Tanezzuft	Tanezzuft
Ordovician	Hennanian	445.6	Memoaniat	Memoaniat	
	Katian	455.1	Meloz Chegrane	Meloz Chegrane	
	Sandbian	460.9			
	Darriwilian	468.1	Haouaz	Haouaz	
	Floian	471.8			
	Fremadocian	488.3		Ash Shubriyat	
Cambrian	Upper	499.0	Hasawanah	Hasawanah	Hasawanah
	Middle	510.0			
	Lower	521.0			
PreCambrian					

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Marine Akakus Sandstone (Silurian) at the eastern margin of Wadi Tanezzuft, western margin of the Murzuq Basin

Period	Age	NW Libya	SW Libya	SE Libya
	Ma	Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian			
Carboniferous	Gzhelian 299	Tiguentourine Fm.		
	Moscovian 311.7	Dembaba	Dembaba	
	Ilashkirian 318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4			
	Visean 345.3	Collana beds	Collana beds	
	Tournaisian 359.2	M'rar	M'rar	
Devonian	Famennian 374.5	Wadi Ash Shari		
	Frasnian 385.3		Awaynat Wanin	Benim
	Givetian 391.8	Awaynat Wanin		
	Eifelian 397.5			
	Emasian 407.0	Qan Qasa	Qan Qasa	Tadrat
	Pargian 411.2	Tadrat	Tadrat	
	Lochkovian 416.0			
Silurian	Pridoli 418.7	Acacus	Acacus	Acacus
	Ludlow 422.9			
	Wenlock 428.2			
	Llandovery 443.7	Tanezzuft	Tanezzuft	Tanezzuft
Ordovician	Hirnatian 445.6	Memouniat	Memouniat	
	Katian 455.1	Melox Chegrane	Melox Chegrane	
	Sandbian 460.9			
	Darriwilian 468.1	Haouaz	Haouaz	
	Floian 471.8			
Cambrian	Fremadocian 485.3		Ash Shubiyat	
	Upper 499.0	Hasawana	Hasawana	Hasawana
	Middle 510.0			
Precambrian	Lower 521.0			



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Lower Devonian Oun Kasa Fm., western margin of the Murzuq Basin, SW Libya.

Period	Age	Ma	NW Libya	SW Libya	SE Libya
			Ghadamis Basin	Murzuq Basin	Al Kufrah Basin
Permian	Permian				
Carboniferous	Gzhelian	299	Tiguentourine Fm.		
	Moscovian	311.7	Dembaba	Dembaba	
	Ilashkirian	318.1	Assedjefar	Assedjefar	Dalma
	Serpukhovian	326.4			
	Viscun	345.3	Collana beds	Collana beds	
	Tournaisian	359.2	M'rar	M'rar	
Devonian	Famennian	374.5	Wadi Ash Shari		
	Frasnian	385.3		Awaynat Wanin	Benim
	Givetian	391.8	Awaynat Wanin		
	Eifelian	397.5			
	Emasian	407.0	Qan Qas	Qan Qas	
	Pargian	411.2	Tadrat		Tadrat
	Lochkovian	416.0			
Silurian	Pridoli	418.7			
	Ludlow	422.9	Acacaus	Acacaus	Acacaus
	Wenlock	428.2			
	Llandovery	443.7	Tanezzuft	Tanezzuft	Tanezzuft
Ordovician	Hemian	445.6	Memouniat	Memouniat	
	Katian	455.3	Melex Chegrane	Melex Chegrane	
	Sandbian	460.9			
	Darivilian	468.3	Haouaz	Haouaz	
	Floian	471.8			
	Tremadocian	488.3		Ash Shubiyat	
Cambrian	Upper	499.0	Hasawanah	Hasawanah	Hasawanah
	Middle	510.0			
	Lower	521.0			
Precambrian					

Лекция 5. Стратиграфия, НГБ и
нефтяные системы Ливии

Period	Age	Ma	NW Libya Ghadamis Basin	SW Libya Murzuq Basin	SE Libya Al Kufrah Basin
Permian	Permian				
Carboniferous	Gzhelian 299		Tiguentourine Fm.		
	Moscovian 311.7		Dembaba	Dembaba	
	Ilashkirian 318.1		Assedjefar	Assedjefar	Dalma
	Serpukhovian 326.4				
	Visean 345.3		Collana beds	Collana beds	
	Tournaisian 359.2		M'rar	M'rar	
Devonian	Famennian 374.5		Wadi Ash Shati		Benim
	Frasnian 385.3		Awaynat	Awaynat	
	Givetian 391.8		Wanin	Wanin	
	Eifelian 397.5				
	Emasian 407.0		Qan Qasa	Qan Qasa	Tadrat
	Pargian 411.2		Tadrat	Tadrat	
Silurian	Lochkovian 416.0				
	Pridoli 418.7		Acacaus	Acacaus	Acacaus
	Ludlow 422.9				
	Wenlock 428.2				
Ordovician	Llandovery 443.7		Tanezzuft	Tanezzuft	Tanezzuft
	Hematan 445.6		Memouniat	Memouniat	
	Katian 455.1		Melox Chegrane	Melox Chegrane	
	Sandbian 460.9				
	Darriwilian 468.1		Haouaz	Haouaz	
Cambrian	Floian 471.8				
	Tremadocian 488.3			Ash Shabtyan	
	Upper 499.0		Hasawana	Hasawana	Hasawana
Precambrian	Middle 510.0				
	Lower 521.0				



Massive lower Devonian fluvial Tadrart Sandstones. Tabular crossbeds, braided river.
Western margin of the Murzuq Basin, SW Libya

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

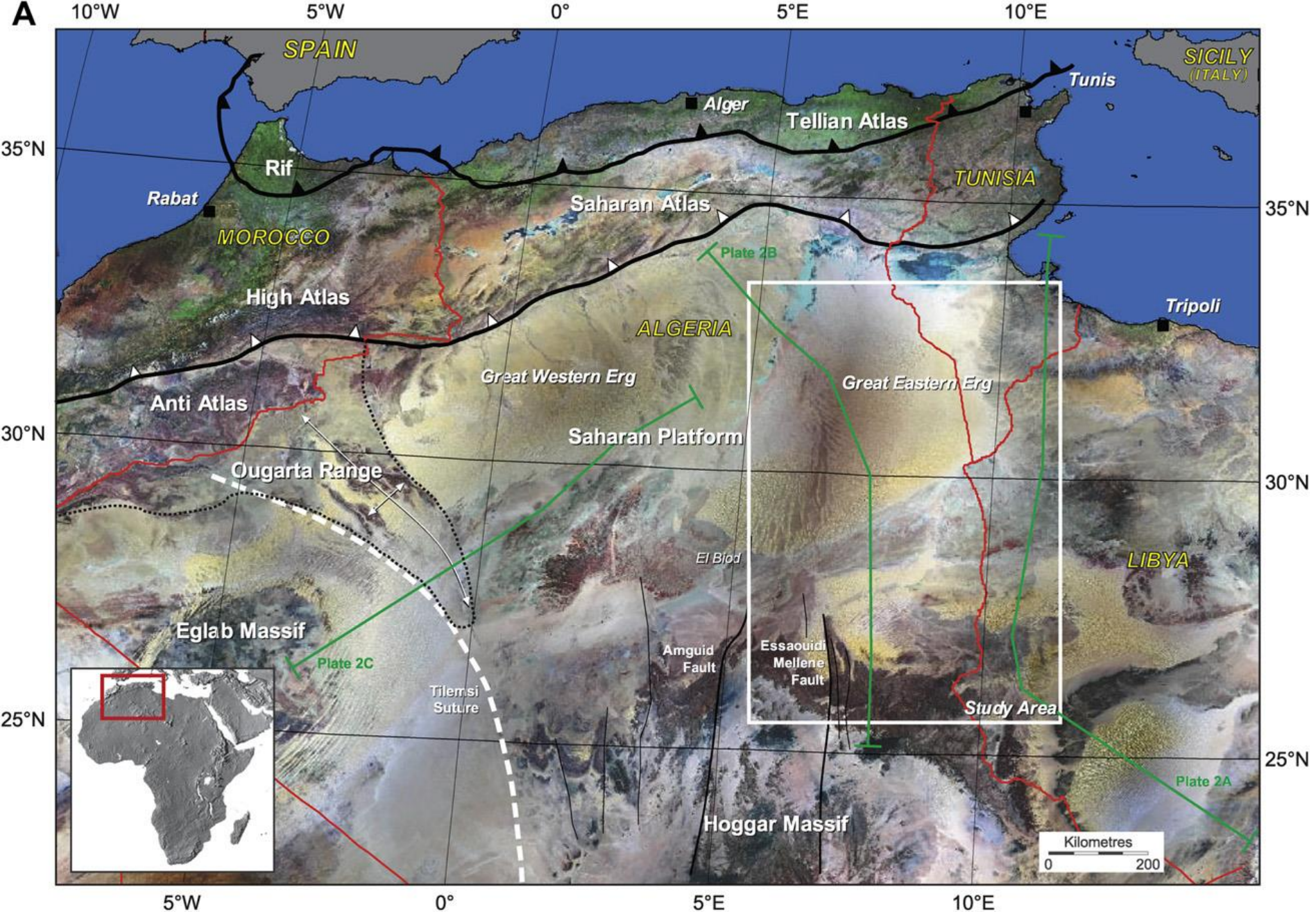
Cyrenaica

Ghadamis

Sirt

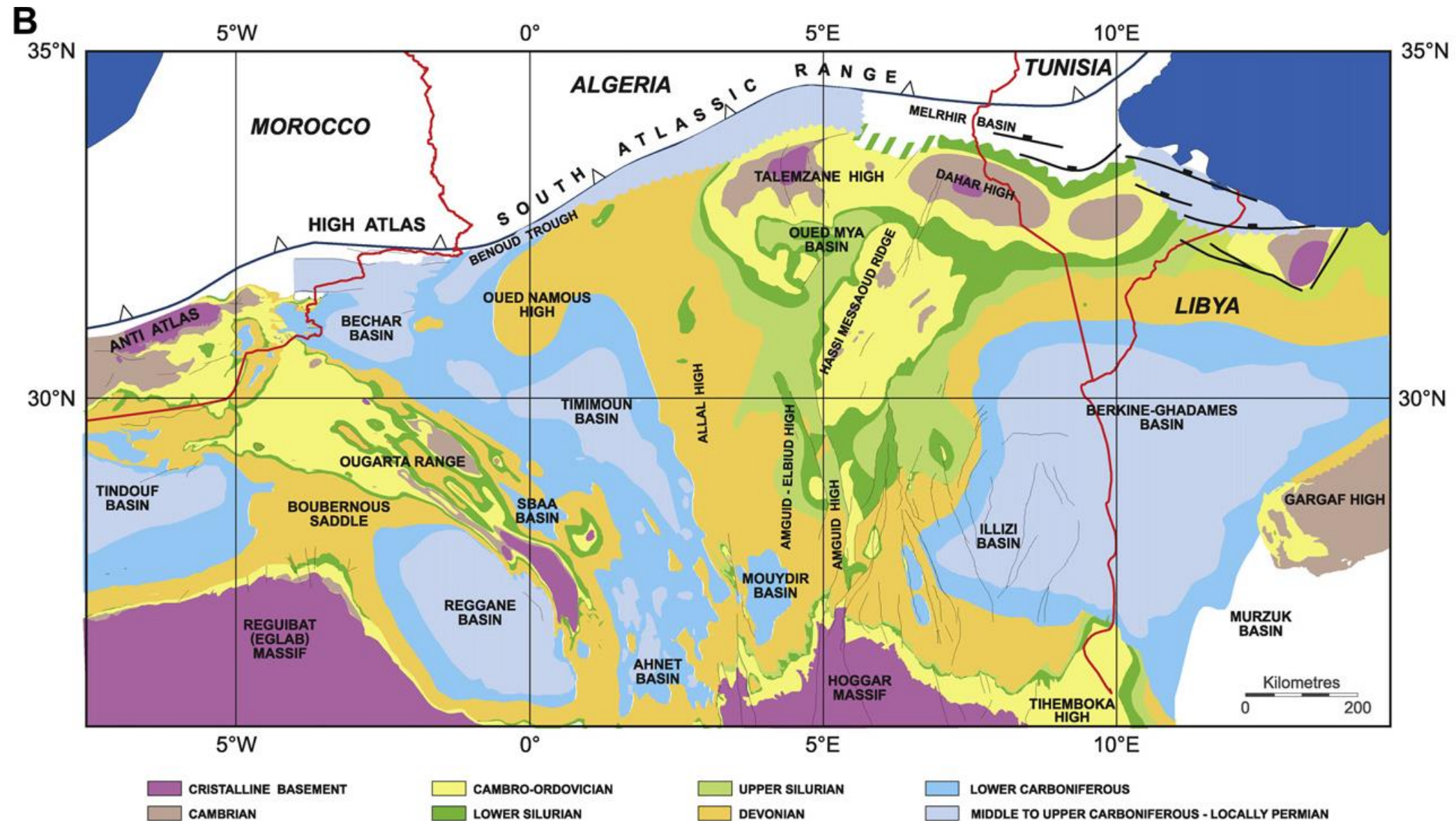
Muruzq

Al Kufrah



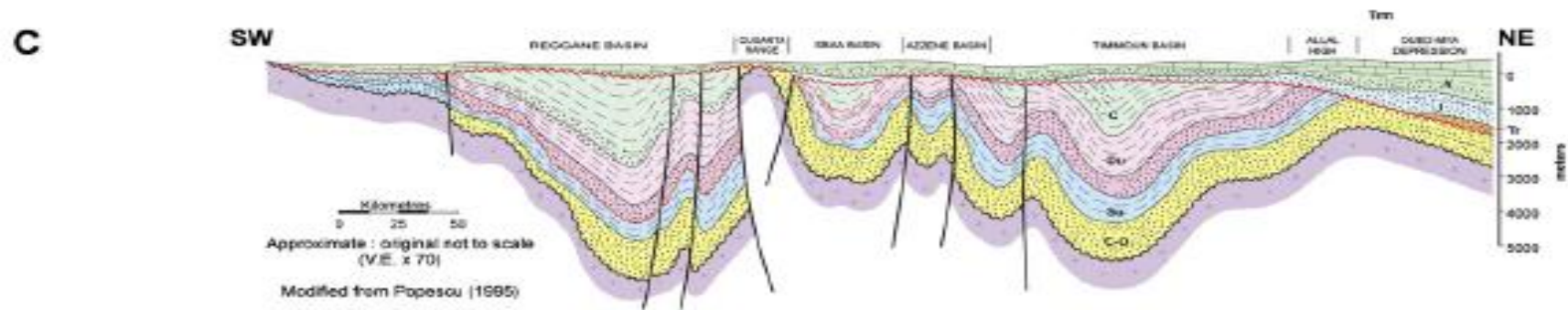
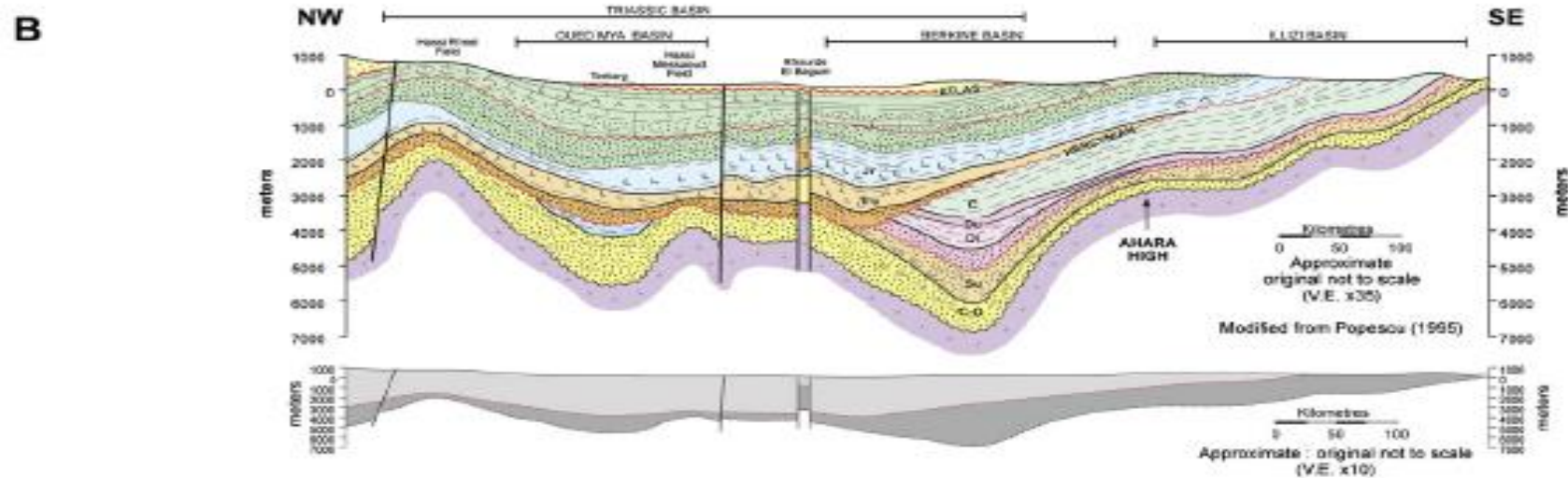
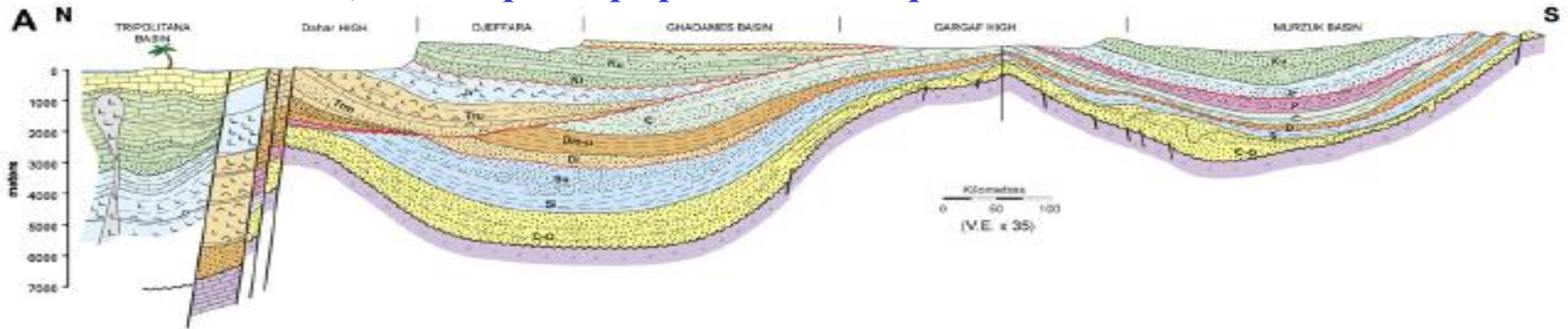
Enhanced satellite image of the Maghreb region (NW Africa), showing the main tectonic domains of the area and the location of the study area (NW Africa). The Berkine–Ghadames and Illizi basins are Palaeozoic intracratonic depressions developed within the Saharan Platform. The Pan-African Tilemsi Suture separates the Eglab and Hoggar massifs. N–S oriented basement faults formed during the Pan-African Orogeny and strongly influenced the structural grain of the Berkine–Ghadames and Illizi basins. The Amguid fault and its continuation into the Amguid–El Biod fault trend bounds both basins to the west.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



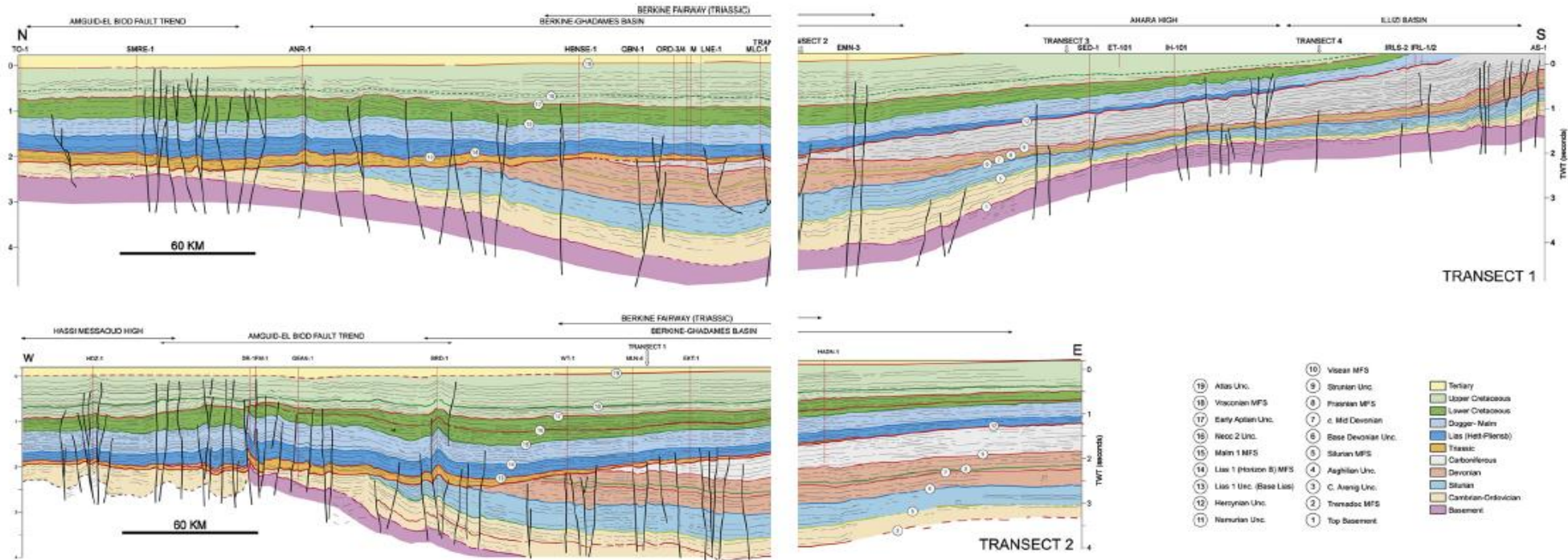
Pre-Mesozoic subcrop map of the Saharan Platform, showing the main Late Palaeozoic (mostly 'Hercynian')–Early Mesozoic tectonic elements.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



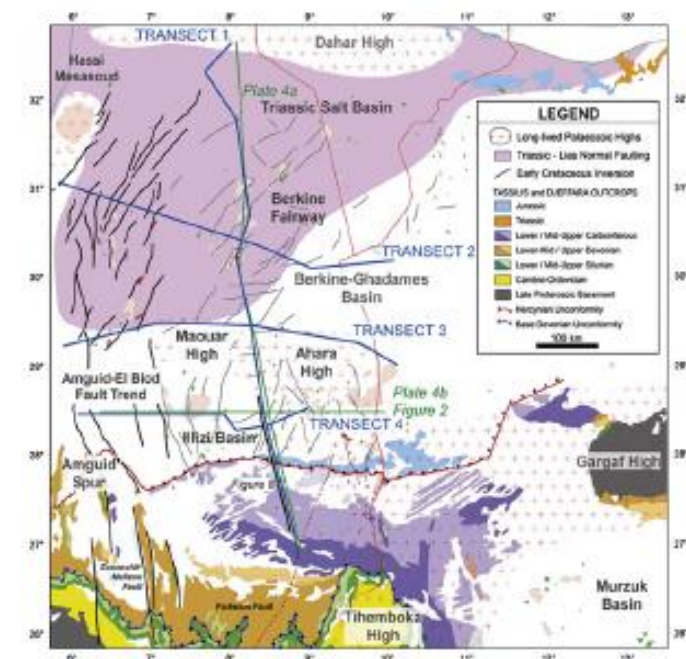
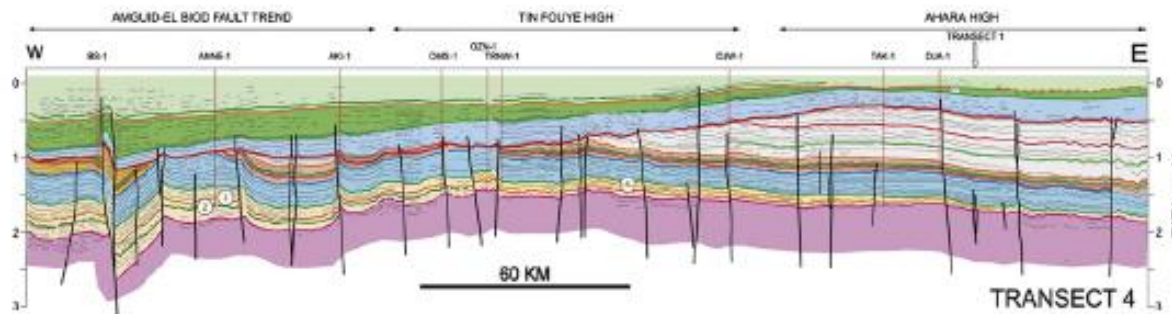
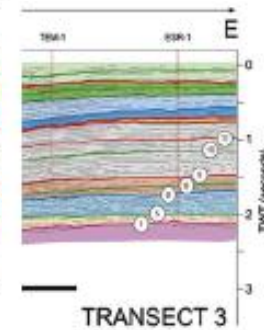
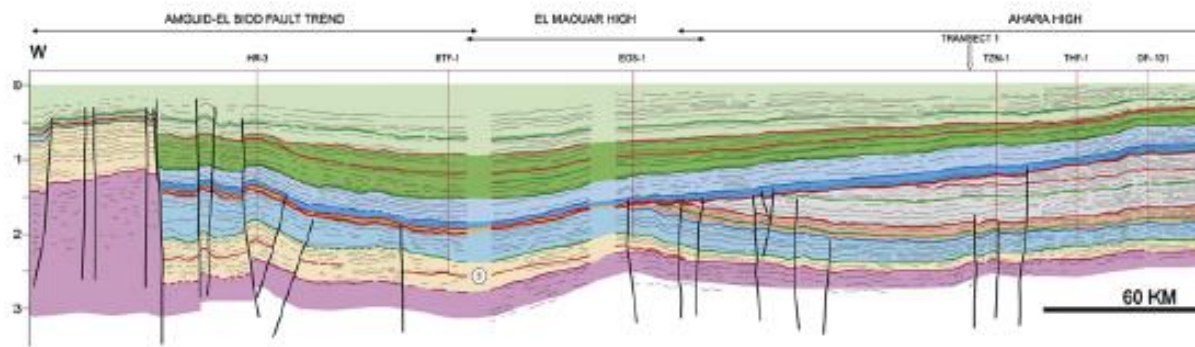
Simplified cross sections across selected portions of the Saharan Platform. The great exaggeration is necessary to give a perspective of the regional setting of these basins. The reader should keep in mind that the dips in the area are indeed very gentle

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Regional seismic line-drawings of the Illizi and Berkine–Ghadames area. Seismic lines have been calibrated by numerous wells. Interpretation of basement marker in the Berkine–Ghadames basin is highly hypothetical. Note the characteristic tectonic styles of high-angle, basement-involved normal, reverse and strike-slip faults of varied age. The times of movement of faults are largely Early Palaeozoic (mostly inferred), Mid Palaeozoic, Hercynian, Triassic, Late Early Cretaceous and Alpine. Note the strongly discordant Mesozoic succession (Tethys Supersequence) lying over deformed Palaeozoic series (Gondwana Supersequence). The inset provides a simplified tectonic-domains map of the Illizi and Berkine–Ghadames area.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



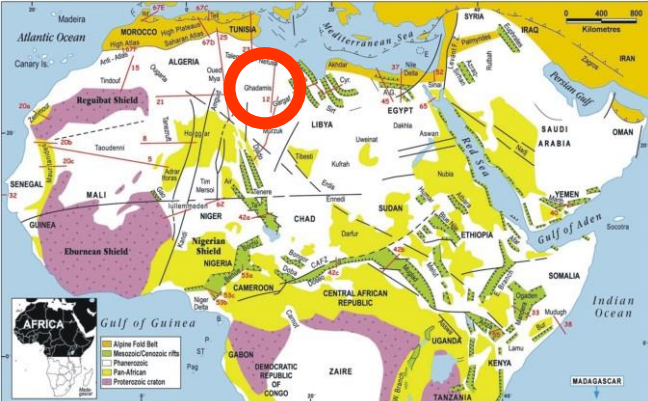
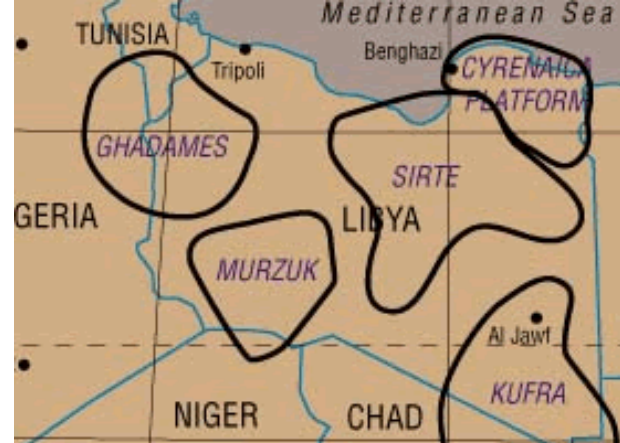
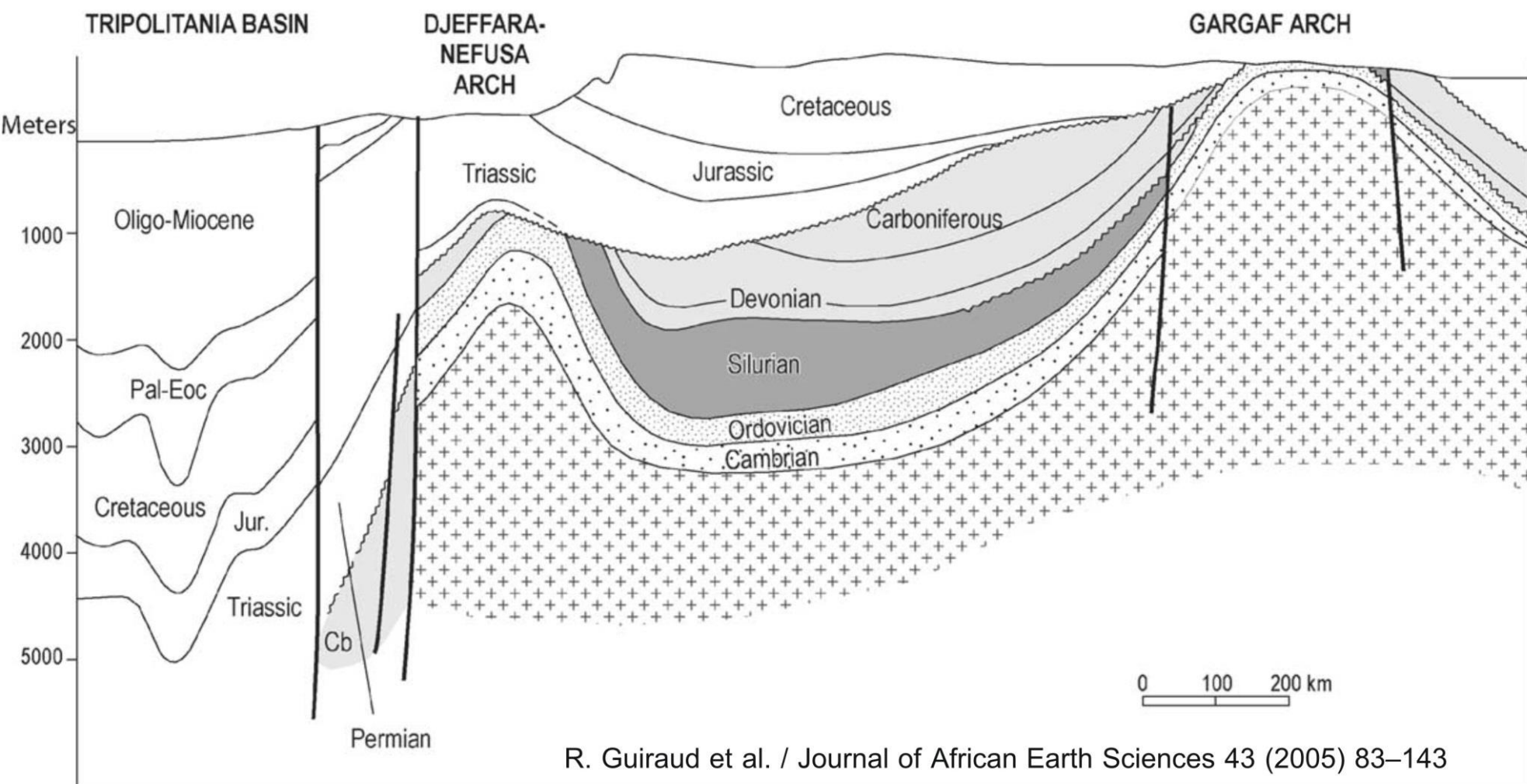


Fig. Schematic geological map of Northern Africa, Central Africa and Arabia
Legend: AG, Abu Gharadig; B, Bioko; CAFZ, Central African Fault Zone; Cyr, Cyrenaica; E, Eratosthenes Seamount; JP, Jos Plateau; P, Principe; Pag, Pagalu; S, Salamat; ST, Sâone; Te, Termit.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



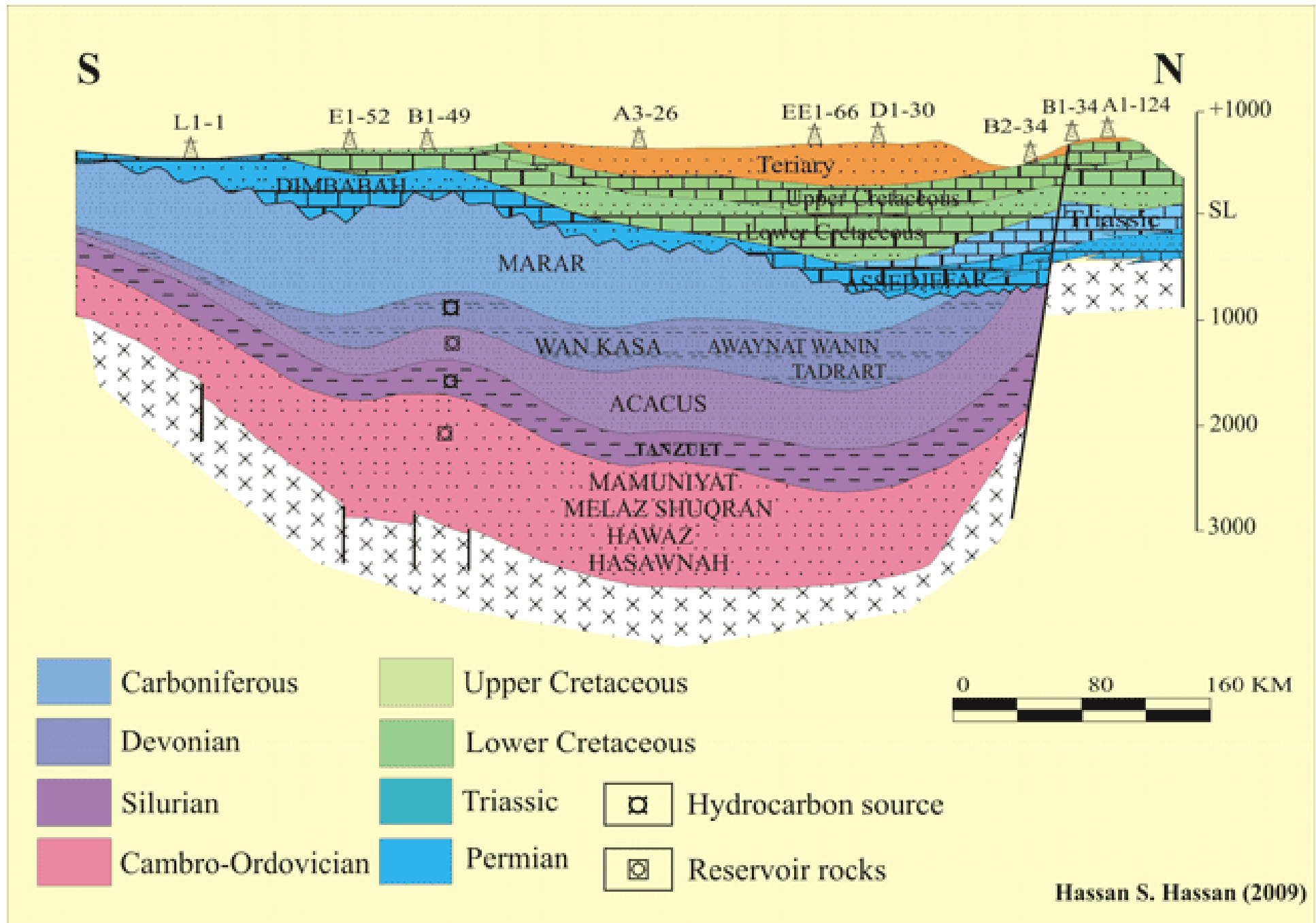
HAMRA-GHADAMIS BASIN



R. Guiraud et al. / Journal of African Earth Sciences 43 (2005) 83–143

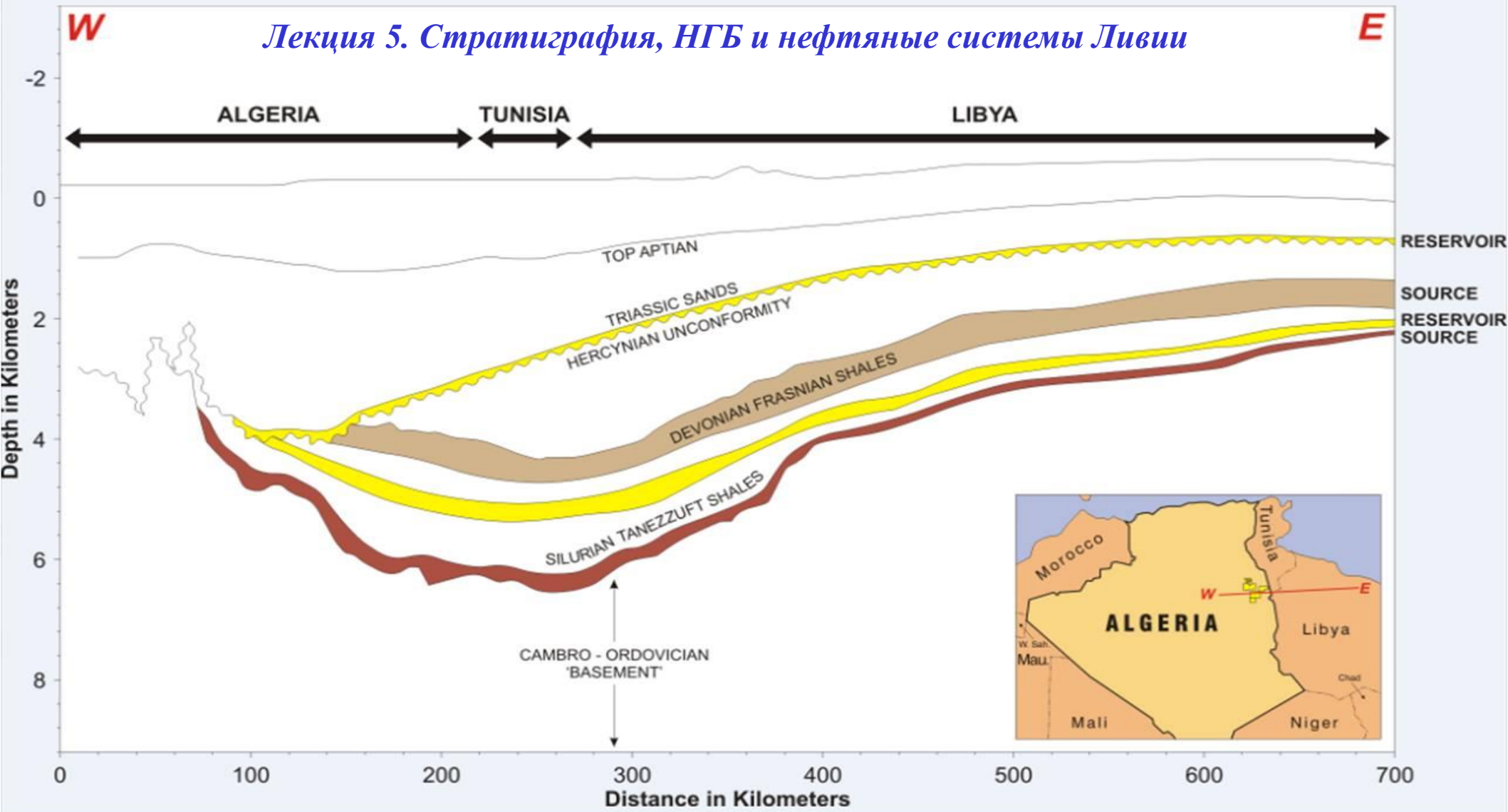
Fig. Schematic geological cross-section across the Hamra-Ghadamis Basin of northwestern Libya

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



North-south cross section of Ghadamis Basin. (Modified after Pallas, 1980)

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



The intracratonic Ghadamis Basin located on the western Libya, southern Tunisia and eastern Algeria. May have oil and gas sourced by Middle-Upper Devonian and Basal Silurian hot shales.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

MURZUQ BASIN

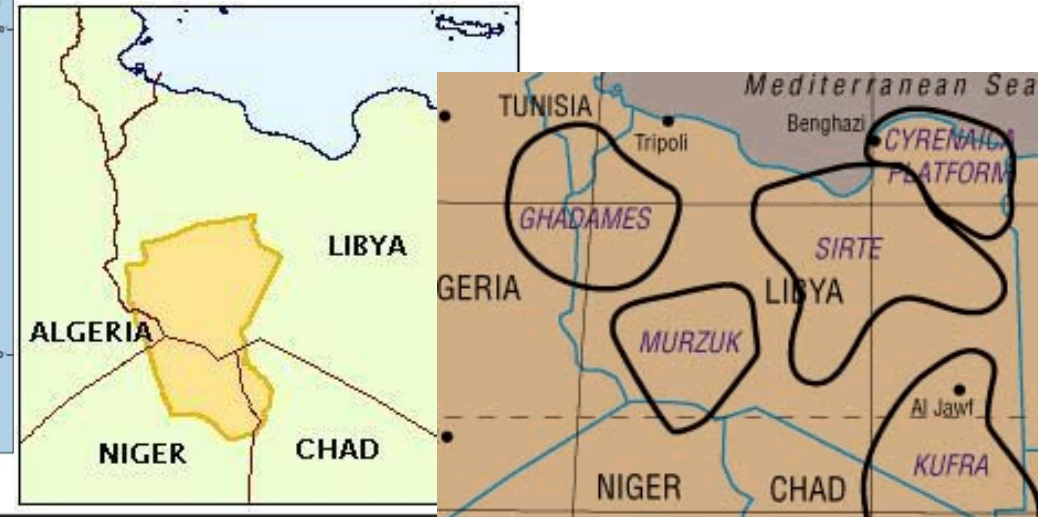
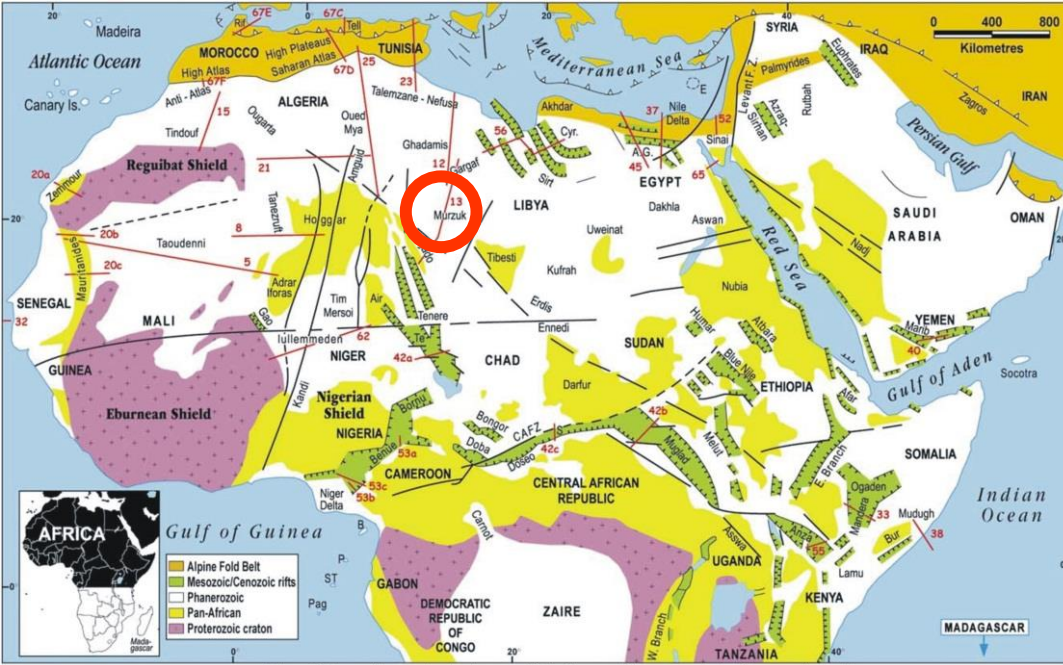
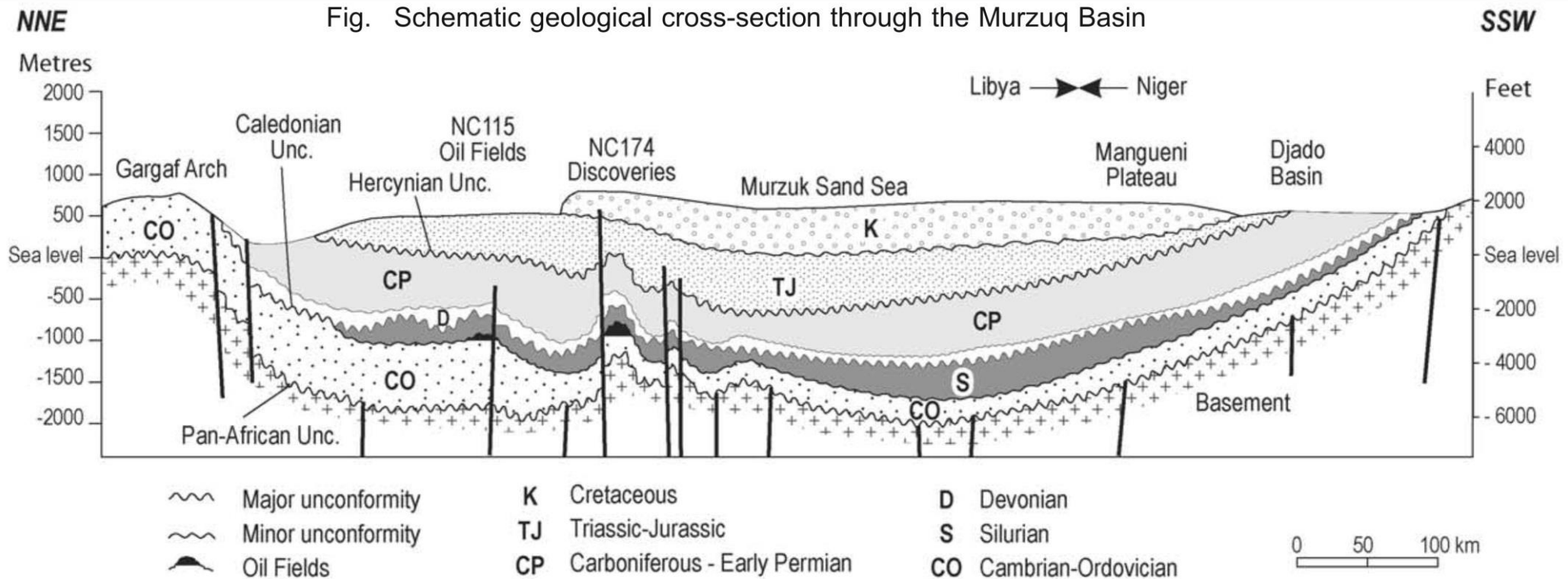


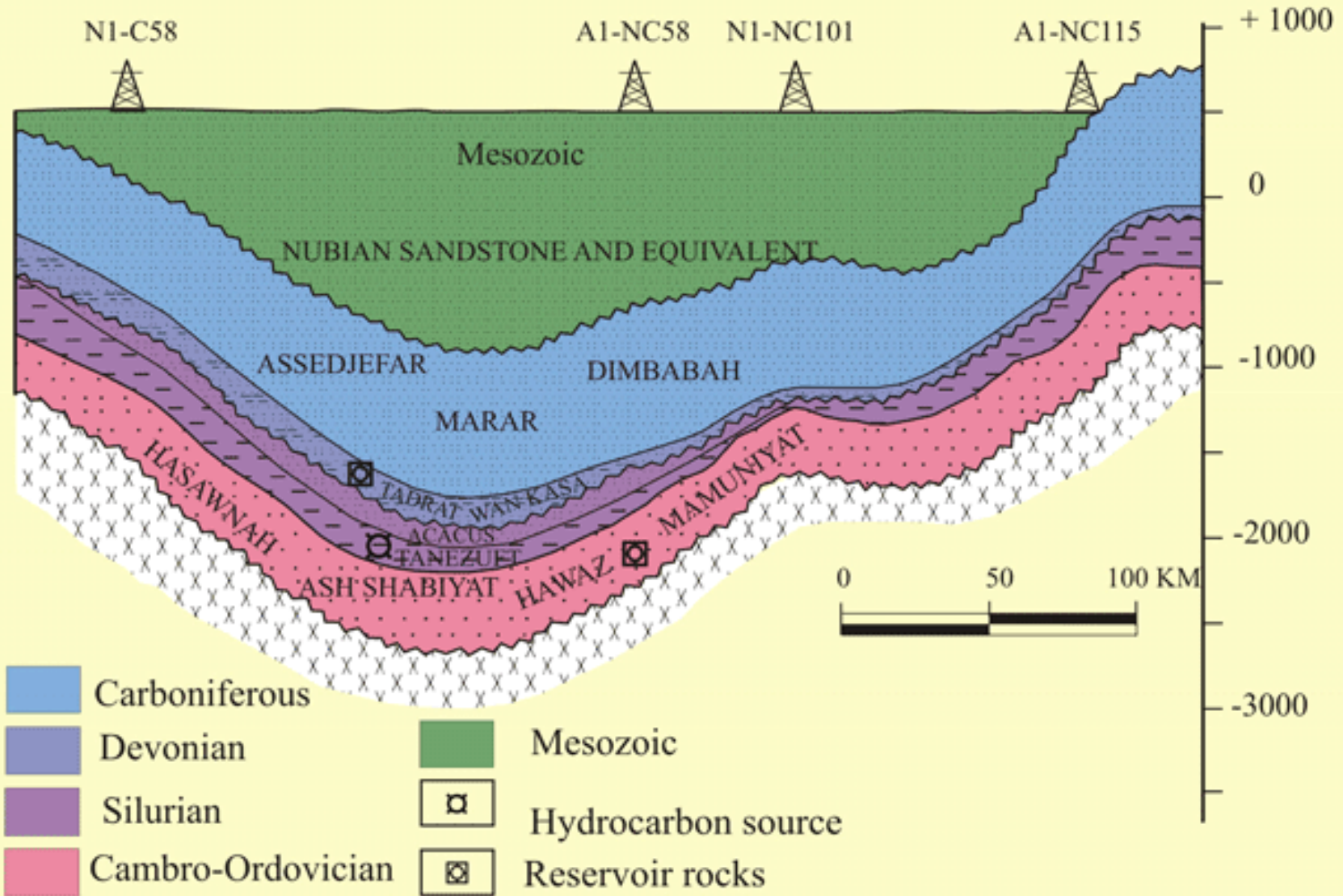
Fig. Schematic geological cross-section through the Murzuq Basin



S

N

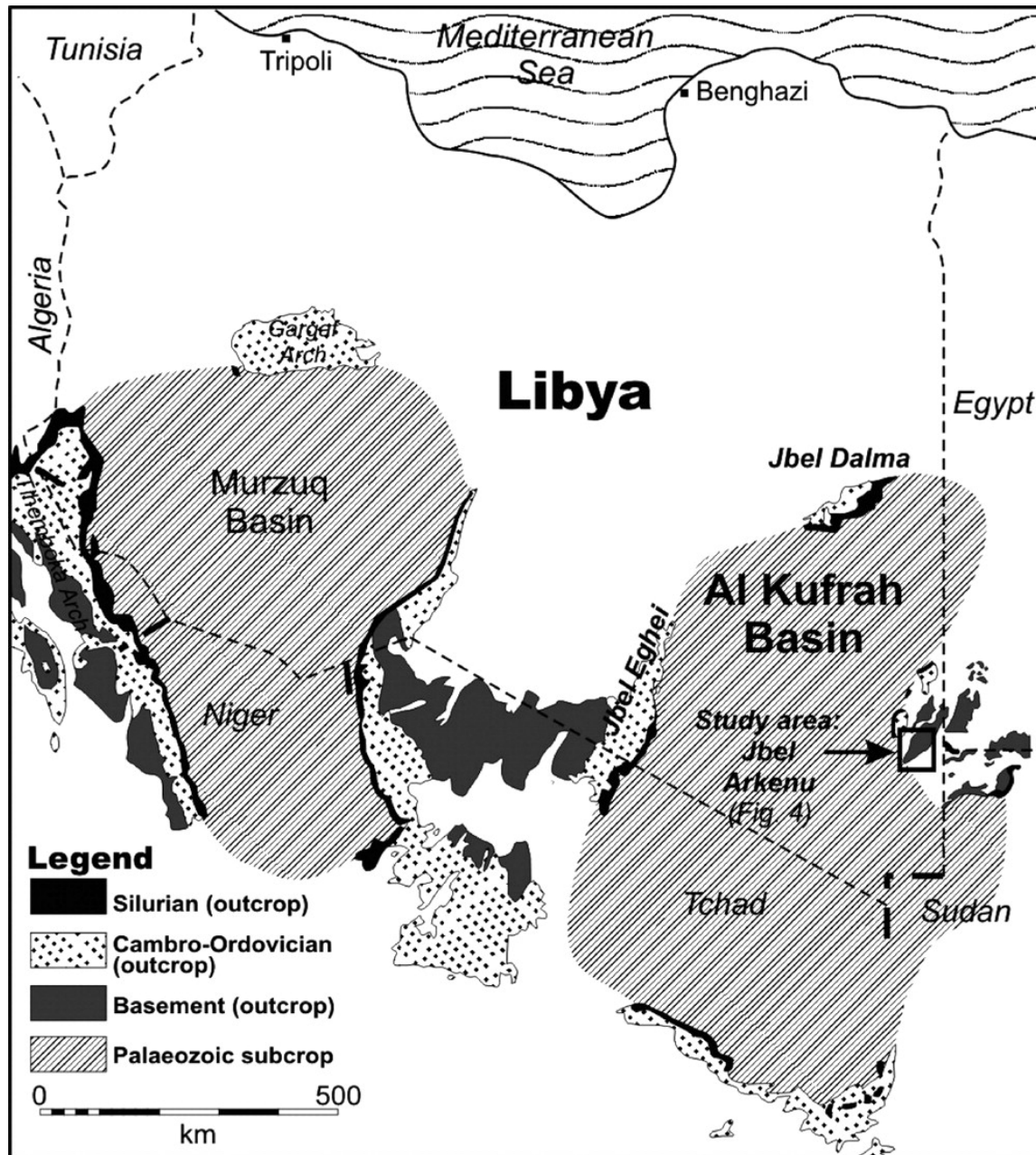
North-south cross section of Murzuq Basin



Hassan S. Hassan (2009)

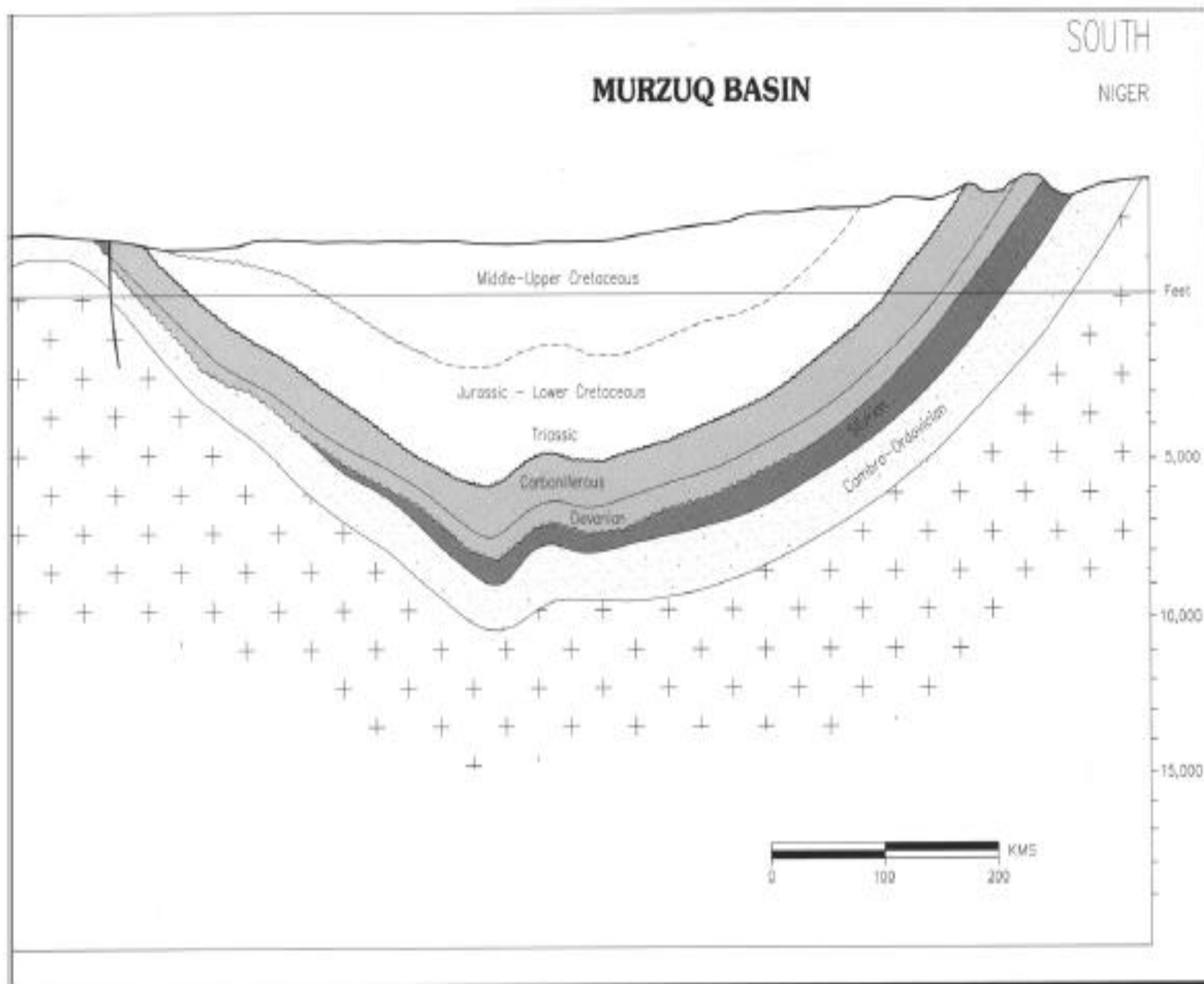
Large intracratonic Paleozoic basin, straddling the boundaries of Algeria, Niger and Chad. The Basin is filled with sediment ranging in age between Cambrian to Quaternary, with maximum total thickness of more than 3000 meter in the central part. The potential reservoirs in Muruzq Basin are mainly siliciclastics that include the Memouniat, Hawaz, Acacus and Tadrart Formations.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

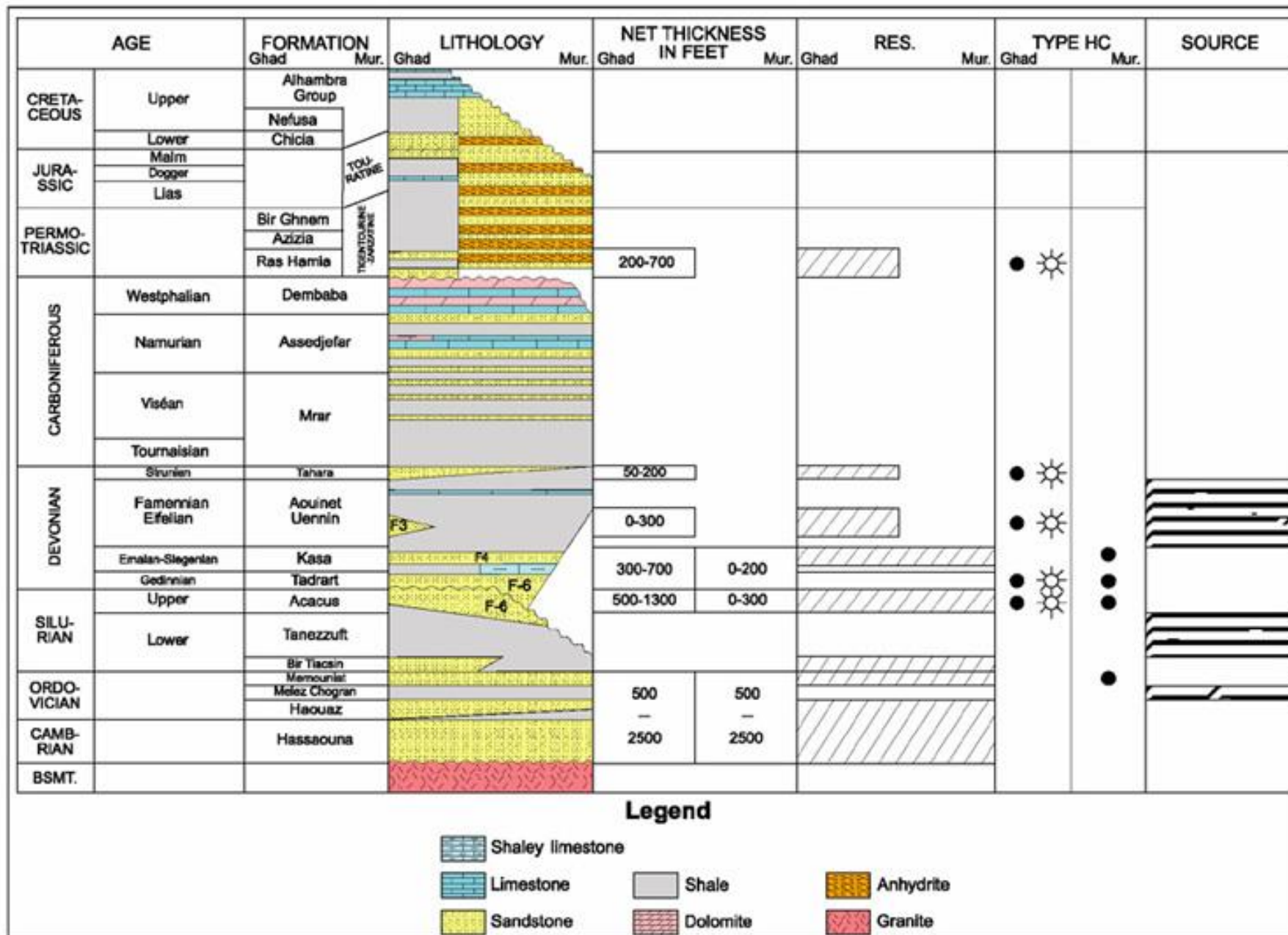


Schematic map

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Generalized stratigraphic chart of Ghadamis and Murzuq Basins, showing source and potential reservoir intervals.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

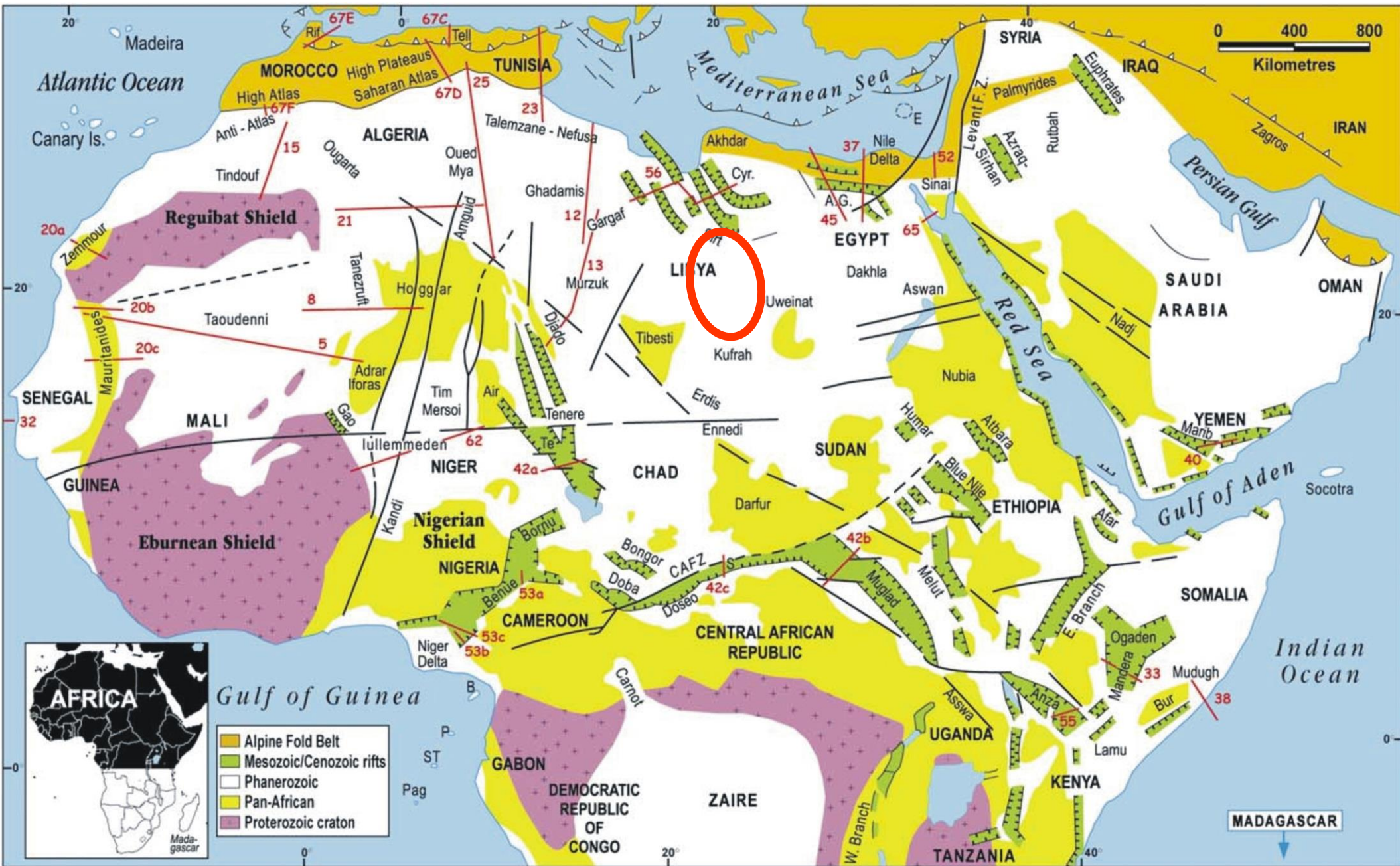
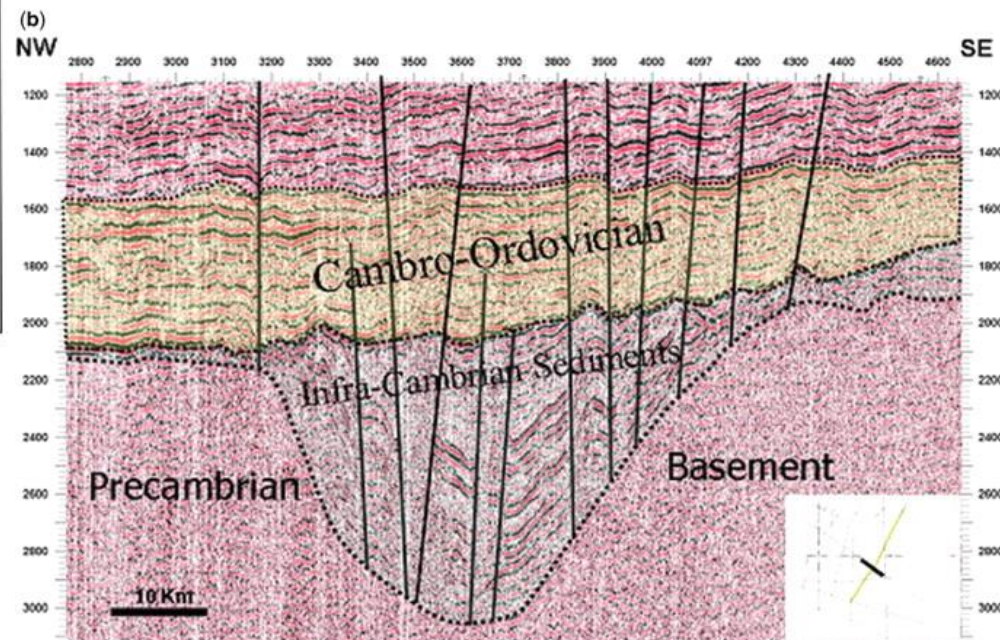
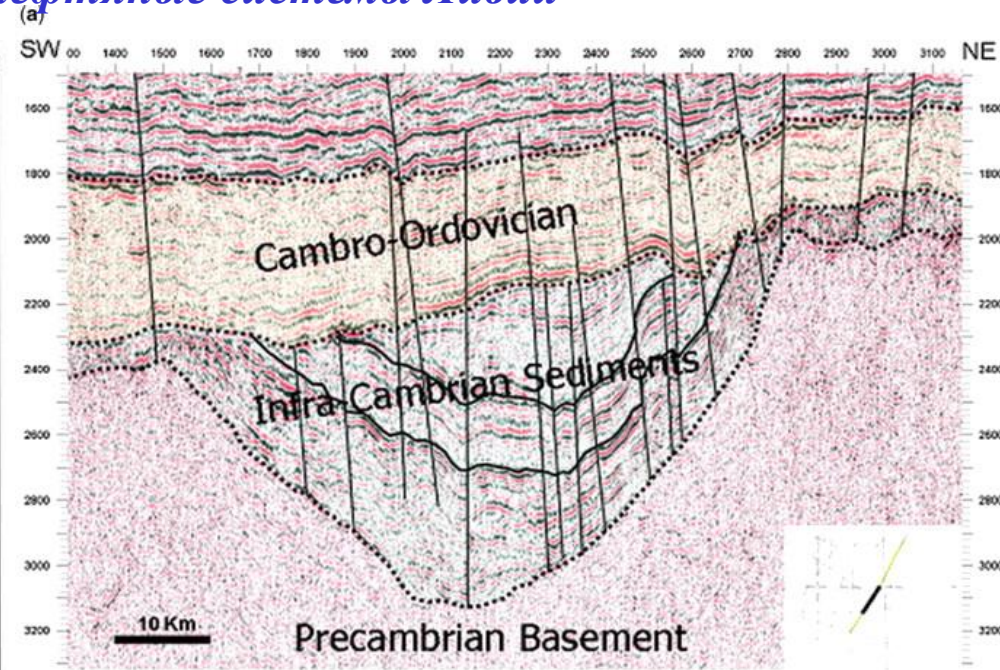
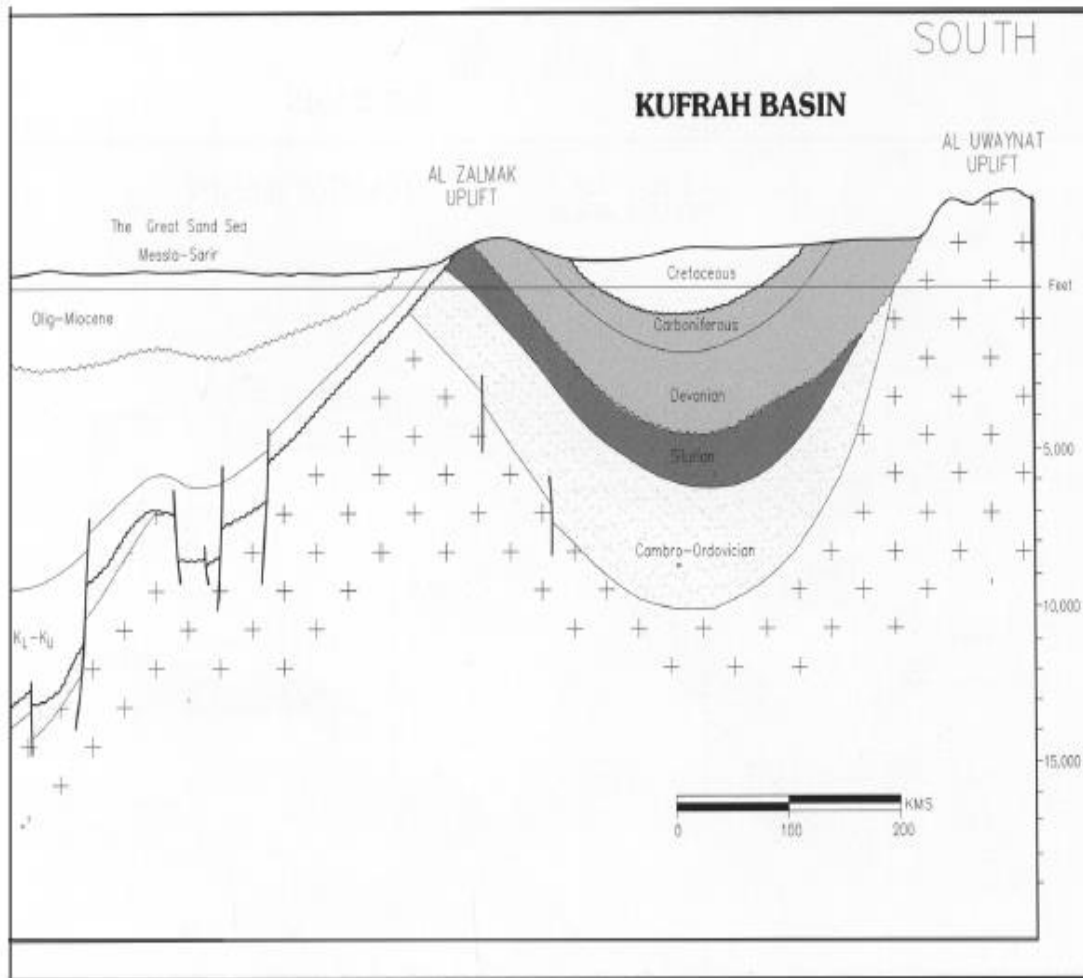


Fig . Schematic geological map of Northern Africa, Central Africa and Arabia

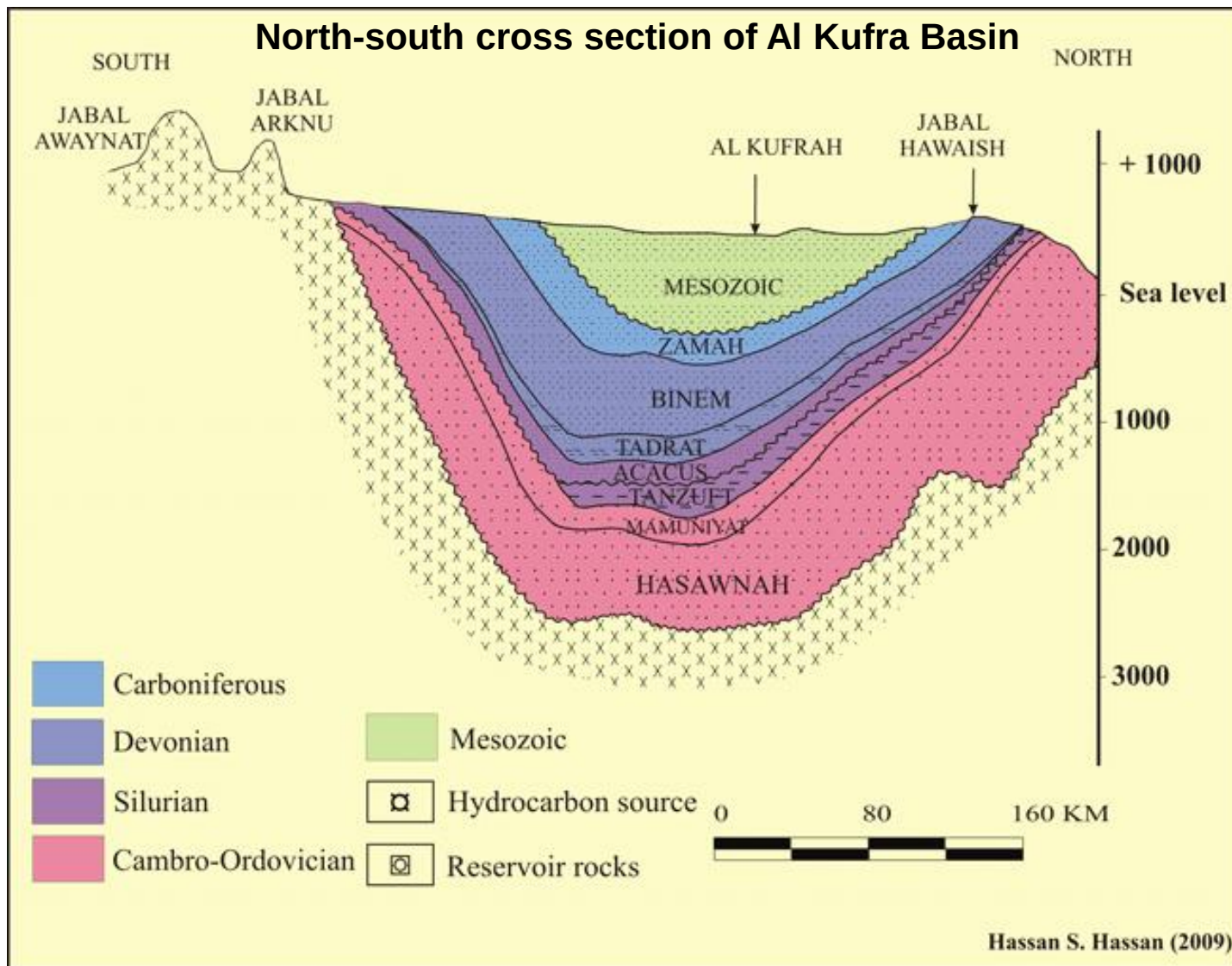
Legend: AG, Abu Gharadig; B, Bioko; CAFZ, Central African Fault Zone; Cyr, Cyrenaica; E, Eratosthenes Seamount; JP, Jos Plateau; P, Principe; Pag, Pagalu; S, Salamat; ST, São Tomé; Te, Termit.

KUFRAH BASIN

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



The intracratonic sag of Al Kufra Basin is oriented northeast-southwest and located in south eastern Libya, it is the third largest Libyan sedimentary basin of about 400,000 km and has structural elements of varying ages and trends. No commercial discovery has been made to this date but hopes remain high and Libya has seen the entry of several American companies with an interest in the Al Kufra Basin over the past two years

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Tectonic history. The regional stratigraphy is continuous across North Africa, but petroleum generation, migration, and entrapment within each total petroleum system have been controlled by the tectonic history of individual basins. Deformational events in the region, most of them minor, are recorded by unconformities reflecting basin tilting, uplift, and erosion of intracratonic structural axes at various times throughout the Phanerozoic. The main deformational events occurred in the Precambrian to Early Cambrian (Pan African event), Late Silurian to Early Devonian, Late Devonian (Frasnian event), Carboniferous to Permian (Hercynian event), Early Jurassic, Early Cretaceous (Aptian, Austrian event), Late Cretaceous, and Tertiary (Eocene to Oligocene, Pyrenean event).

Throughout most of the Paleozoic, North Africa was a single depositional basin on the northern shelf of the African craton.

The Hercynian event marks the collision between Laurasia and Gondwana and caused regional uplift, folding, and erosion.

Several transgressive-regressive cycles occurred throughout the Paleozoic. Two major flooding events, one in the Silurian and the other in the Late Devonian, were responsible for the deposition of source rocks. Many of the prograding fluvial, estuarine, deltaic, and shallow marine sands that were deposited during these cycles are now reservoirs.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Caledonian unconformity, northern Dor El Gusa. Marine Silurian Akakus Fm beds, overlain with angular unconformity by Devonian sandstones



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

Caledonian Unconformity at central Dor El Gusa, west of Wau El Kebir, eastern margin of the Murzuq Basin, SW Libya. Angular unconformity separates Silurian Tanezzuft shales and mid (?) Devonian sandstones



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

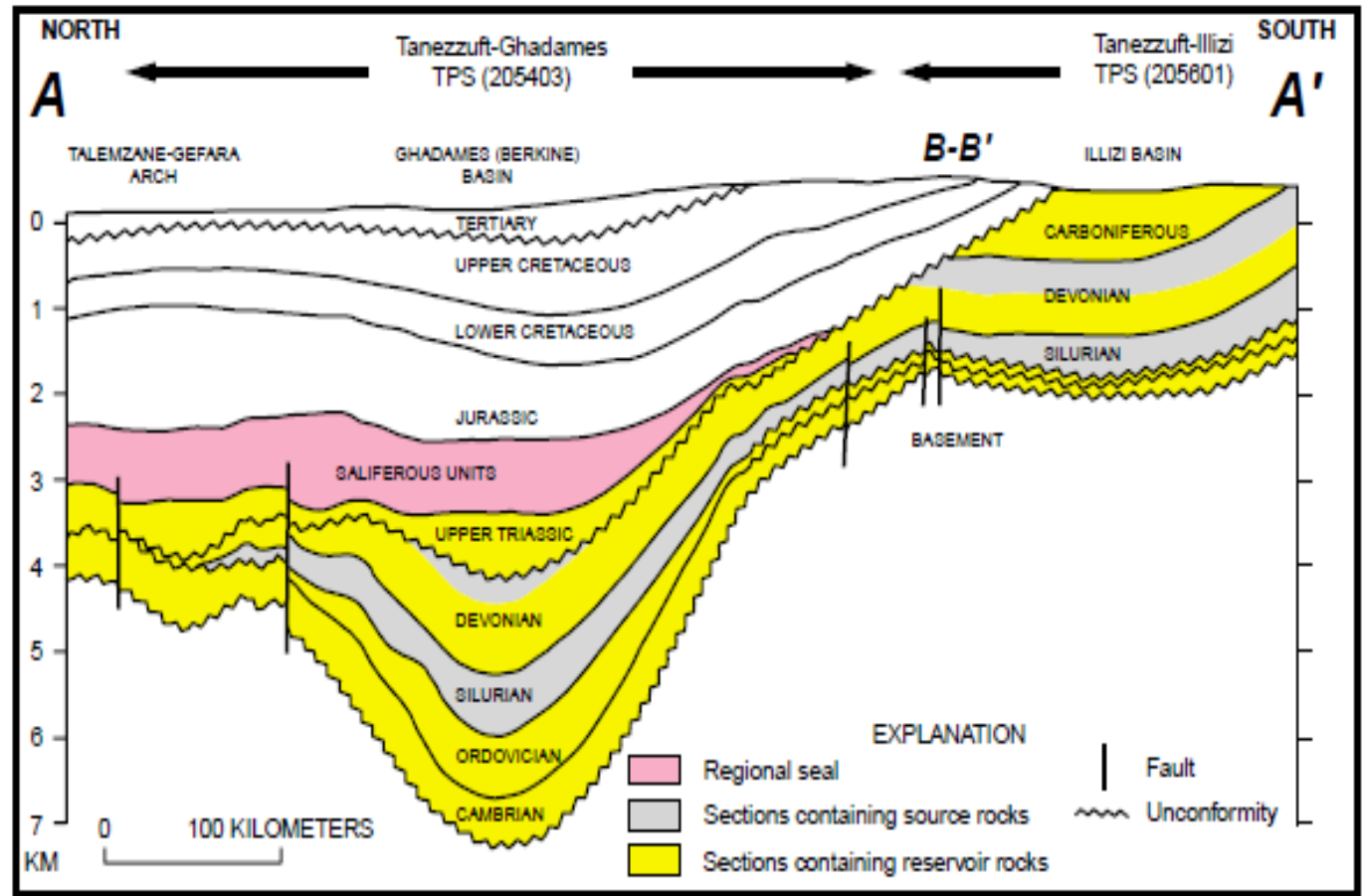
Table 1

Tectonic evolution and major tectonically enhanced unconformities in the Berkine-Illizi region of the Saharan Platform.

Tectonic event	Time interval	Major tectonically enhanced unconformities	Remarks
Alpine Orogeny s.l.	Mid Miocene–Quaternary	Not studied	Regional uplift of Saharan Platform, minor continental deposition during Miocene–Quat. Emplacement of Tellian nappes
Alpine Orogeny s.l. Atlasic Phase and Hoggar Uplift	Mid–Late Eocene	Atlasic Unc (Late Cretaceous–Palaeogene)	$\sigma 1$ N160° E. Regional Uplift and northerly tilting of Saharan Platform. Over 2000 m uplift of Hoggar Massif, associated with Eocene volcanism
Alpine Orogeny, Early Atlasic Phase	Santonian–Maastrichtian	Atlasic Unc (Late Cretaceous–Palaeogene)	$\sigma 1$ N–S Onset of African–Eurasia Collision. Transpressional reactivation of N–E oriented structures in the Berkine and El Biod area
Early Cretaceous Tectonism	Late Neocomian–Ea Aptian	Early Aptian Unc	$\sigma 1$ N160° E. Sinistral Transpression along N–S faults in El Biod–Anguid region. Numerous tight “pop-up” anticlines
Tethys Rifting	Late Permian–Triassic–Jurassic	Hercynian Unc (Late Carboniferous–Mid Triassic), TRIAS 3 Unc (Norian)	$\sigma 3$ N130° E. Extensional deformation linked to opening of Tethys Ocean. Accompanied by local thermal uplift and volcanism of Ladinian–Norian age
Hercynian Orogeny Permian Uplift	Late Devonian–Late Carboniferous	Hercynian Unc (Late Carboniferous–Mid Triassic), Namurian Unc, Strunian Unc (Dev–Carb Boundary)	$\sigma 1$ NE–SW. Local transpressional reactivation of N–S oriented structures in El Biod Trend. Regional uplift and possible lithospheric buckling. Major erosion of pre–Late Carboniferous Palaeozoic series
Caledonian Regime	Late Silurian–Early Devonian	“Base Devonian” Unc, Pragian Unc	$\sigma 1$ Roughly E–W. Local fault reactivation and associated folding in Ahara and Tihemboka high region
Extensional Arenigian Event	Late Tremadocian–Early Arenigian	Arenig Unc (Ea. Arenigian) “Seq–Ord2 SB; base of Hamra Quartzite”	$\sigma 3$ E–W. Tectonic subsidence along Illizi basin centre. Major erosion on Ahara high and NE Berkine areas
Pan-African Orogeny	Late Proterozoic	“Infra Tassilis Unc” (Top Basement)	$\sigma 1$ E–W. Major Orogeny due to collision of East and West African Cratons. Major uplift and pervasive N–S faulting and folding that define regional basement grain. Orogen’s metamorphic and igneous root comprises basement of Berkine–Illizi area

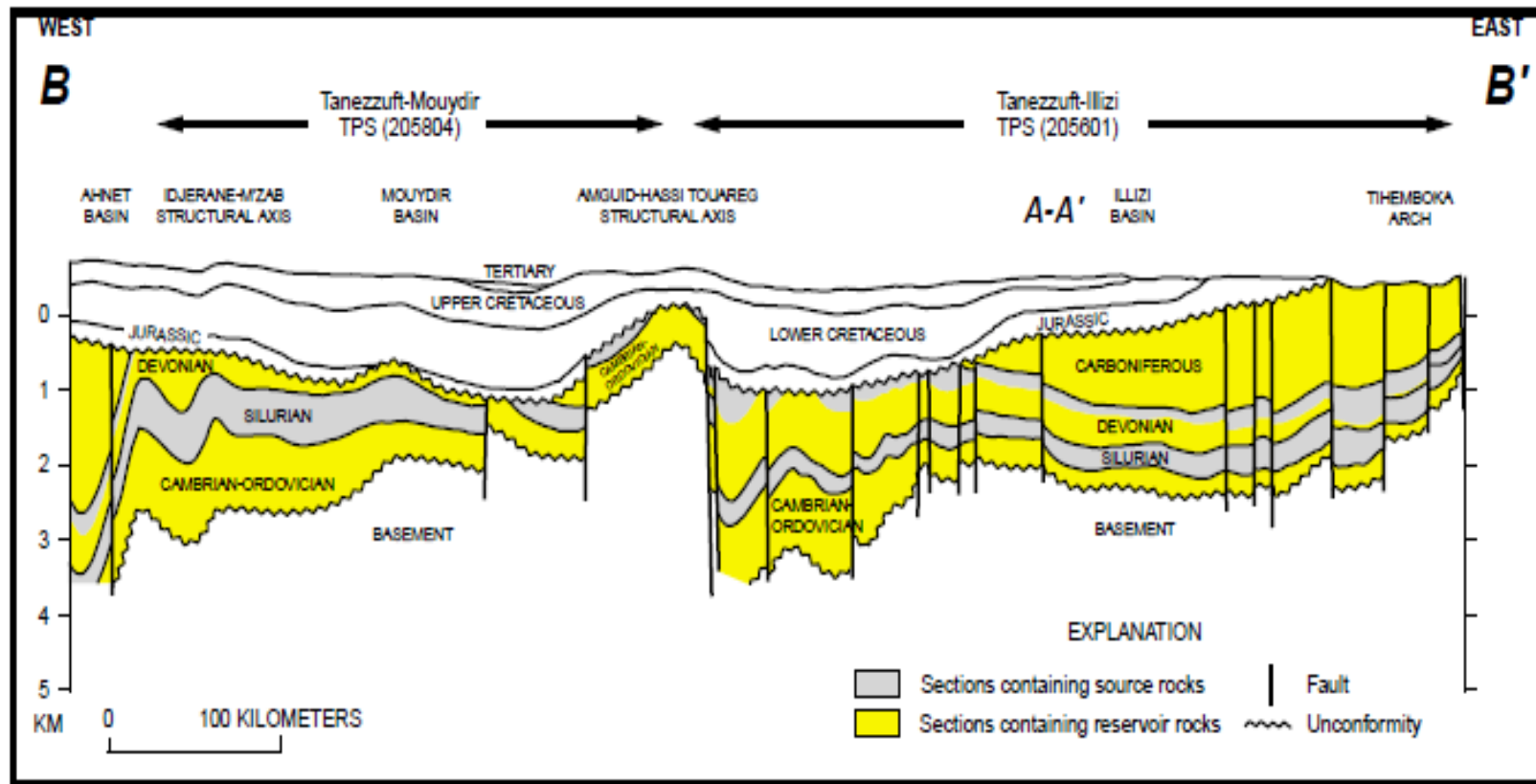
Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

During the early Mesozoic, extensional movements caused by the opening of the Tethys and Atlantic oceans developed a cratonic sag basin called the Triassic Basin. The depocenter was superimposed on some of the Paleozoic basins



Triassic fluvial sands followed by a thick Triassic to Jurassic evaporite section were deposited within the sag basin. Sandstones resulting from the fluvial deposition are major reservoirs, and the evaporites provide a regional seal for these fluvial and Paleozoic reservoirs. Clastic then carbonate deposition occurred throughout the remainder of the Mesozoic over much of central North Africa. Sediment deposition gradually diminished in the Tertiary over most of the area. **Much of the petroleum** present in Saharan Africa was generated in the Cretaceous and early Tertiary.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Transpressional movements (wrenching) **during Austrian** deformation reactivated older structures such as those along the Tihemboka Arch and Amguid-Hassi Touareg structural axis, causing local uplift and erosion. The southern portion of the Illizi Basin was unroofed at this time and was never again reburied.

The initial stages of the Africa-Arabia and Eurasia collision during Late Cretaceous to middle Tertiary caused compressional movements and uplift. These movements tilted the Triassic Basin to its present configuration

Petroleum was generated within the Illizi Basin from the Middle to Late Jurassic to early Tertiary. Some spillage or secondary migration occurred. Many of the structural traps were formed by vertical movements of the basement during Mesozoic and Tertiary deformational events

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

System	Stage	Illizi Basin (van de Weerd and Ware, 1994)	Triassic Basin (Boudjema, 1987)	Ghadames (Berkine) and Hamra Basins (Montgomery, 1994; Echikh, 1998)	General lithology (Boudjema, 1987)	Description (Boudjema, 1987)
Carboniferous	Stephanian	F	Tiguentourine	Dembaba		Mudstone, limestone, and gypsum
	Westphalian		El Adeb Larache			Limestone, gypsum, and mudstone
	Namurian	E	Oubarakat	Assed Jeffar		Limestone and sandstone
		D	Assekalfat			Limestone and sandstone with concretions
	Visean	C	Issendjel	Mrar		Mudstone and sandstone
		B				Limestone and mudstone
	Tournaisian	A	(Sbaa)			Limestone and mudstone
Devonian	Strunian	F2	Gara Mas Melouki	Tahara (Shatti)		Sandstone
	Famen - Frasnian	F3	Tin Meras	Aouinet Ouenine		Sandstone
	Givetian - Eifelian		Orsine	Ouan Kasa		Mudstone and limestone
	Emsian	F4-5				Mudstone and sandstone
Silurian	Siegenian - Gedinian	F6	Hassi Tabankort	Tadart		Sandstone
			Zone de Passage	Acacus		Sandstone and mudstone
Ordovician	Cardocian	Gara Louki	Gres de Remada	Bir Tlacin		Sandstone
			Argile Microgl.	Memountat		Microconglomeratic mudstone
	Llandellian - Llanvmlian	Edjeleh	Gres d'Oued Salet	Melez Chograne		Limestone, sandstone, and mudstone
	Arenigian	Hamra	Argiles d'Azzel	Haouaz		Silty black mudstone
			Gres de Ouargla			Sandstone
	Tremadocian	In Kraf	Quartzites De Hamra			Sandstone
			Gres d'El Athane			Sandstone and mudstone
			Argile d'El Gassi	Achebyat		Mudstone
Cambrian	Hassi Lella	Hassi Messakout	Zone des Alternances			Sandstone and mudstone
			R0			Sandstone
			R2			Sandstone
Infra-Cambrian			R3	Hassaouna and Mourizidie		Sandstone and conglomerate
			Socle	Infra Tassilian/ Mourizidie		Metamorphic and magmatic rocks

System	Stage	Illizi Basin (Chaouchi and others, 1998)	Triassic, Ghadames (Berkine), and Hamra Basins (Montgomery, 1994)	General lithology (Boudjema, 1987)	Description (Boudjema, 1987)
Neogene	Pliocene				Conglomerate
					Marl, gypsum, and sandstone
Paleog.	Miocene				Gypsum, marl, limestone, sandstone, and conglomerate
					Sandstone and marl
Cretaceous	Oligocene	Al Hamra Group			Limestone and marl
	Eocene				Pyrenean Unconformity
	Paleocene				Limestone and marl
					Calcaire
					Marnes
					Calcaire
	Senonian				Argile Gypse
					Anhydrite, limestone, dolostone, marl, and mudstone
	Turonian				Limestone and dolostone
	Cenomanian				Anhydrite, dolostone, and marl
Jurassic	Albian	Serie de Taouratine	Nefousa Group		Sandstone, mudstone, and dolostone
	Aptian				Austrian Unconformity
	Barremian				Continental Intercalaire
					Sandstone and mudstone
	Neocomian				Cabao
					Sandstone and dolomitic mudstone
Triassic	Malm	Zarzaltine Supérieur	Tigi		Soesoluch (Shakshuk)
					Anhydrite, limestone, dolostone, marl, and sandstone
	Dogger				Mudstone, sandstone, limestone, and anhydrite
					Salt, anhydrite, and mudstone
Triassic	Lias	Zarzaltine Moyen	Saliferous Units		Salt, anhydrite, and mudstone
					Salt, anhydrite, and mudstone
					Salt, anhydrite, and mudstone
					Salt, anhydrite, and mudstone
Triassic		Zarzaltine Inférieur	Argilo-Greseux Supérieur (Gassi Touli)		Sandstone, mudstone, salt, and volcanic rocks
					Argilo-Carbonate (Oued Nani)
					Argilo-Greseux Inférieur (Nezia)
Triassic					Hercynian Unconformity
					Hercynian Unconformity

Columnar section and stratigraphic nomenclature for Illizi, Triassic, and Ghadames (Berkine) Basins. Major reservoir rocks are shown in yellow, source rocks in gray, and seals in red.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

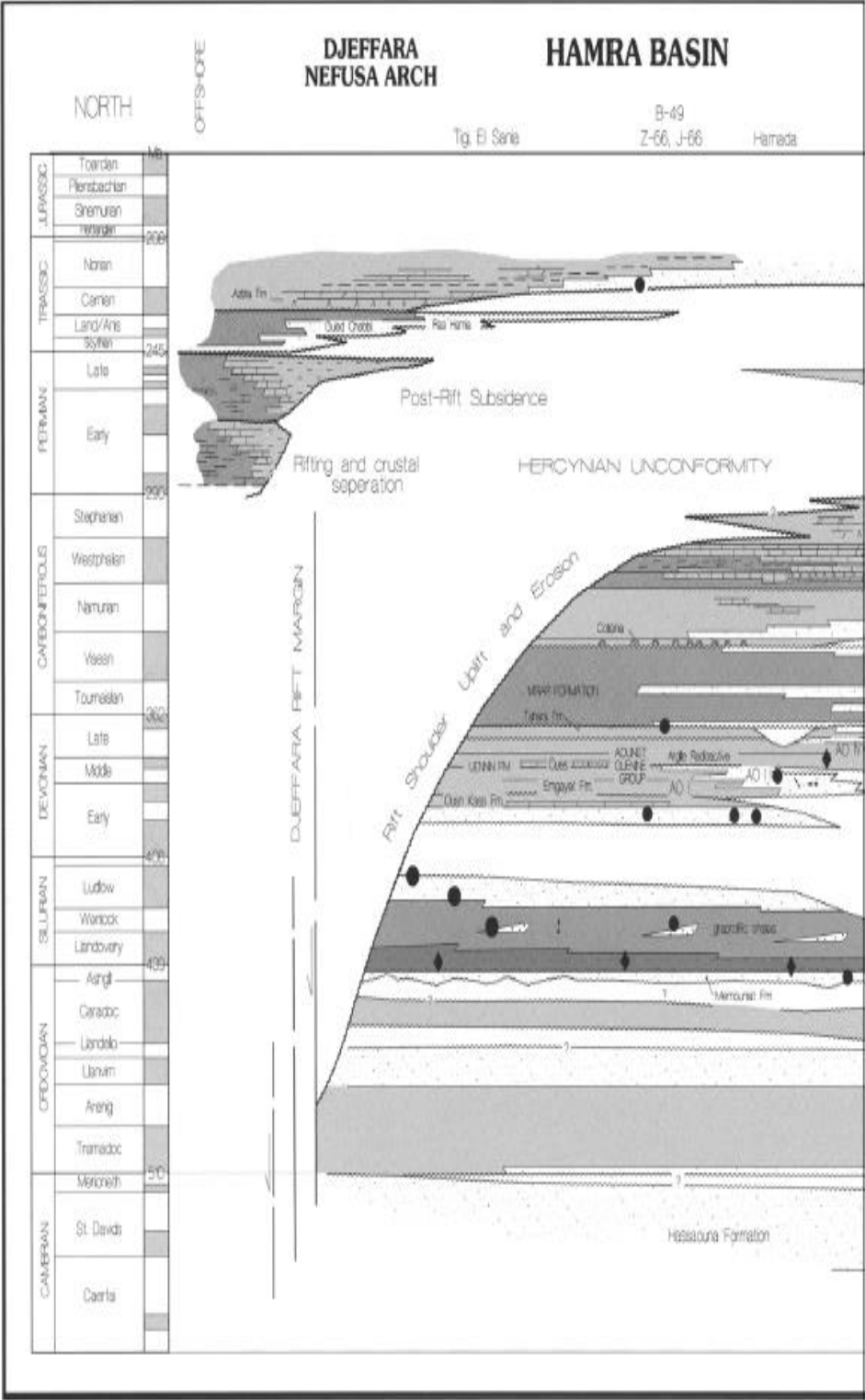
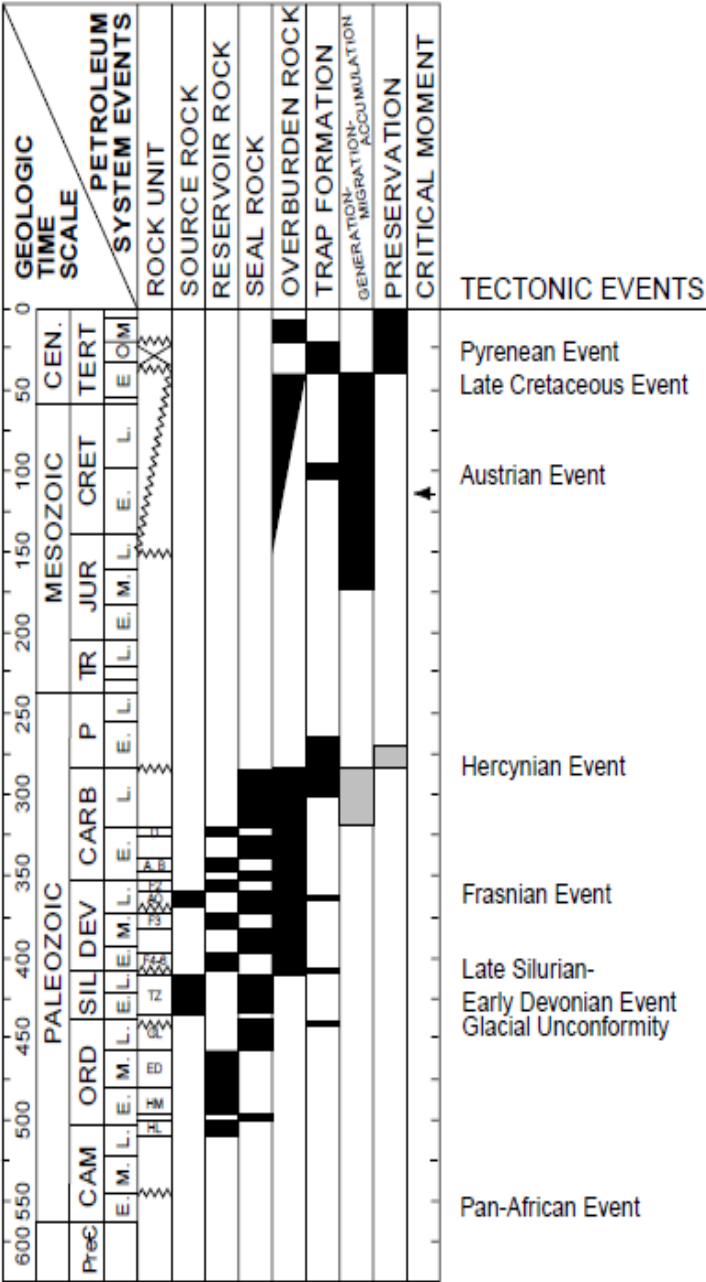
Бассейн Иллизи (Алжир, рядом с границей с Ливией)

TPS Name: Tanezzuft-Illizi (205601)

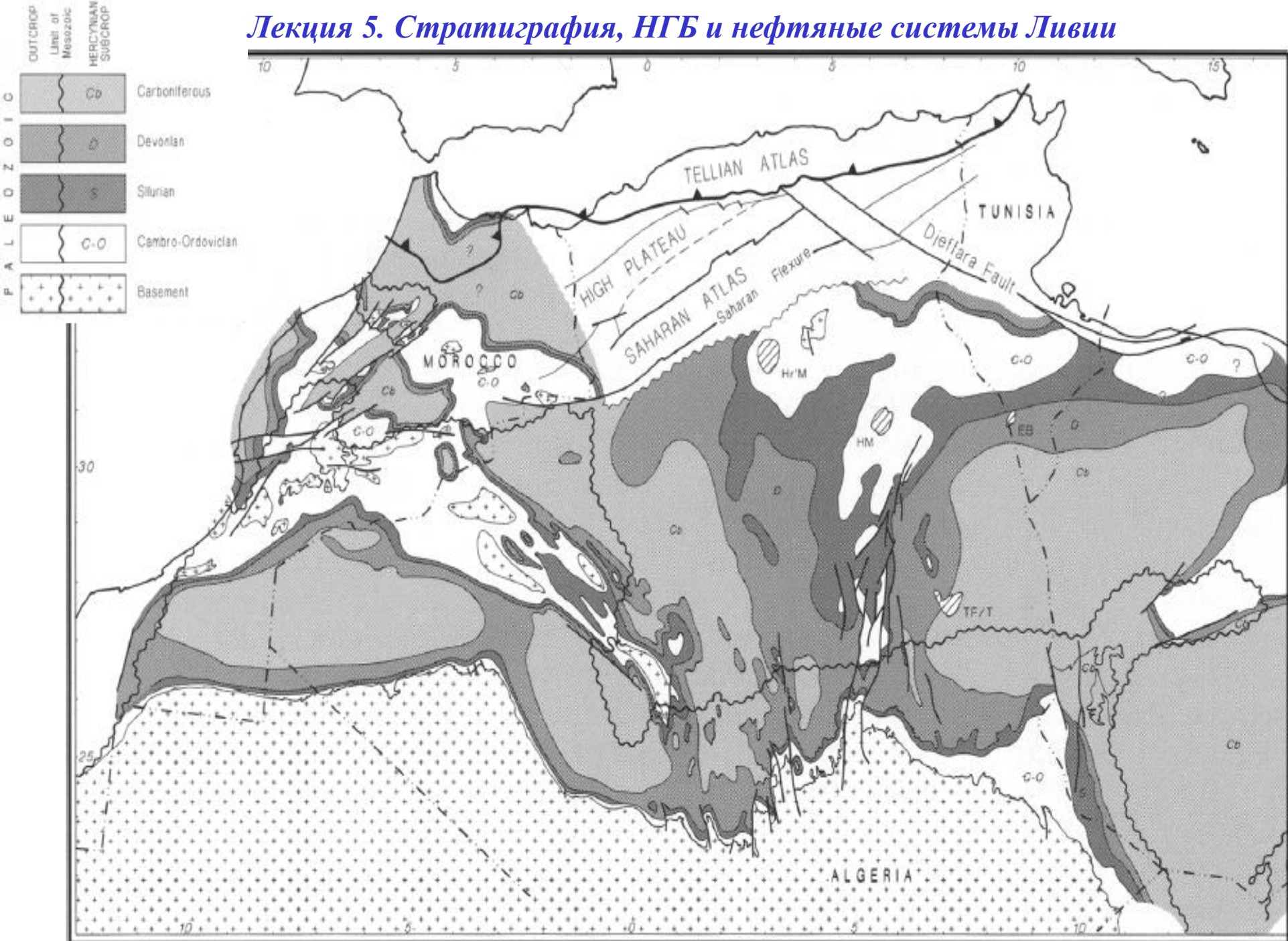
Province Name: Illizi Basin (2056)

Author(s): Timothy R. Klett

Date: 11-15-98

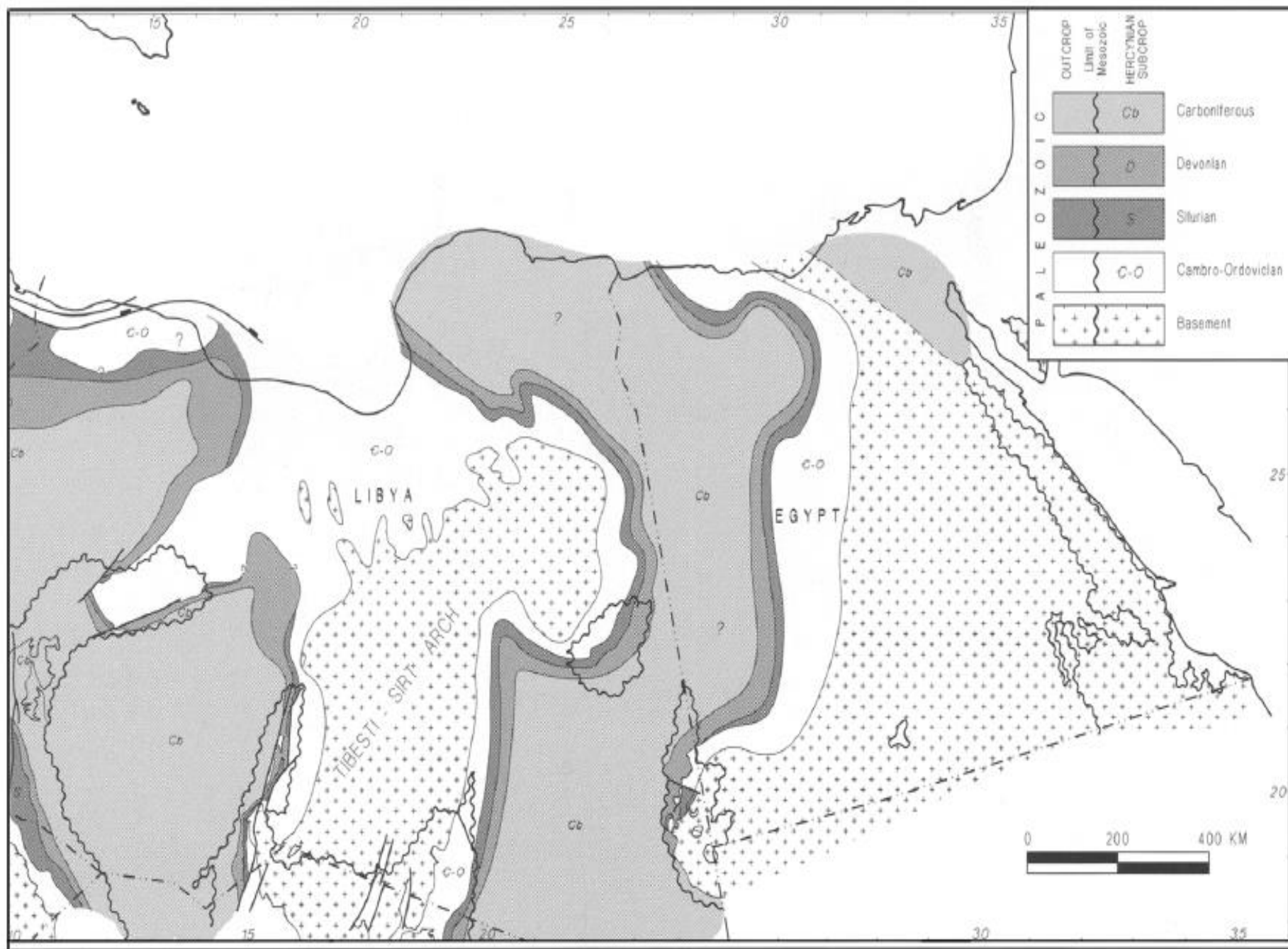


Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

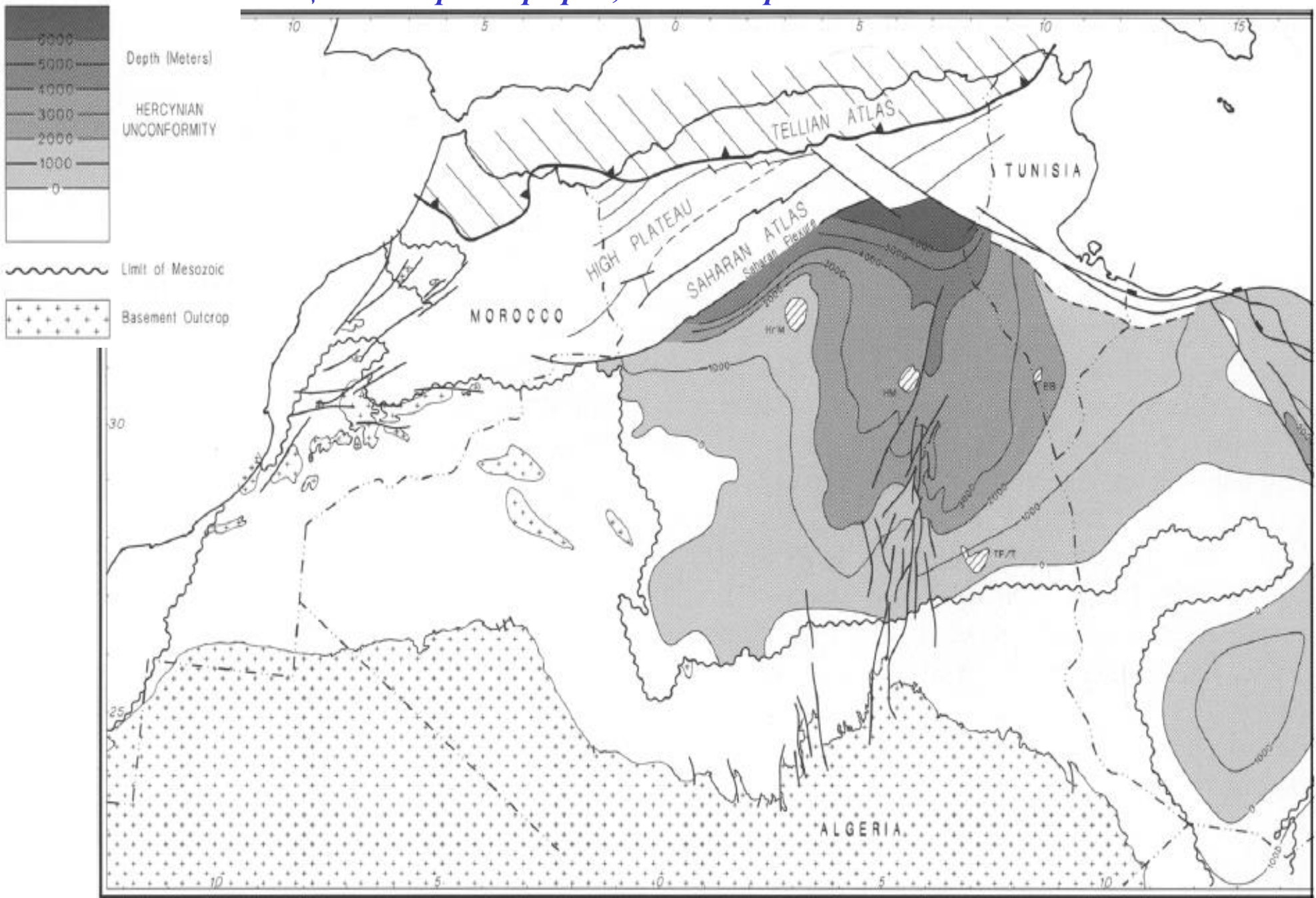


Palaeozoic outcrop and subcrop distribution below the Hercynian unconformity. The present-day the Ougarta Ridge, Talemzane and Hassi Messaoud Arches, the Gargaf High and the Tibesti-Sirt Arch, modified distribution in the Algerian Atlas and north of the Djeffara fault trend is uncertain and not shown on this map

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

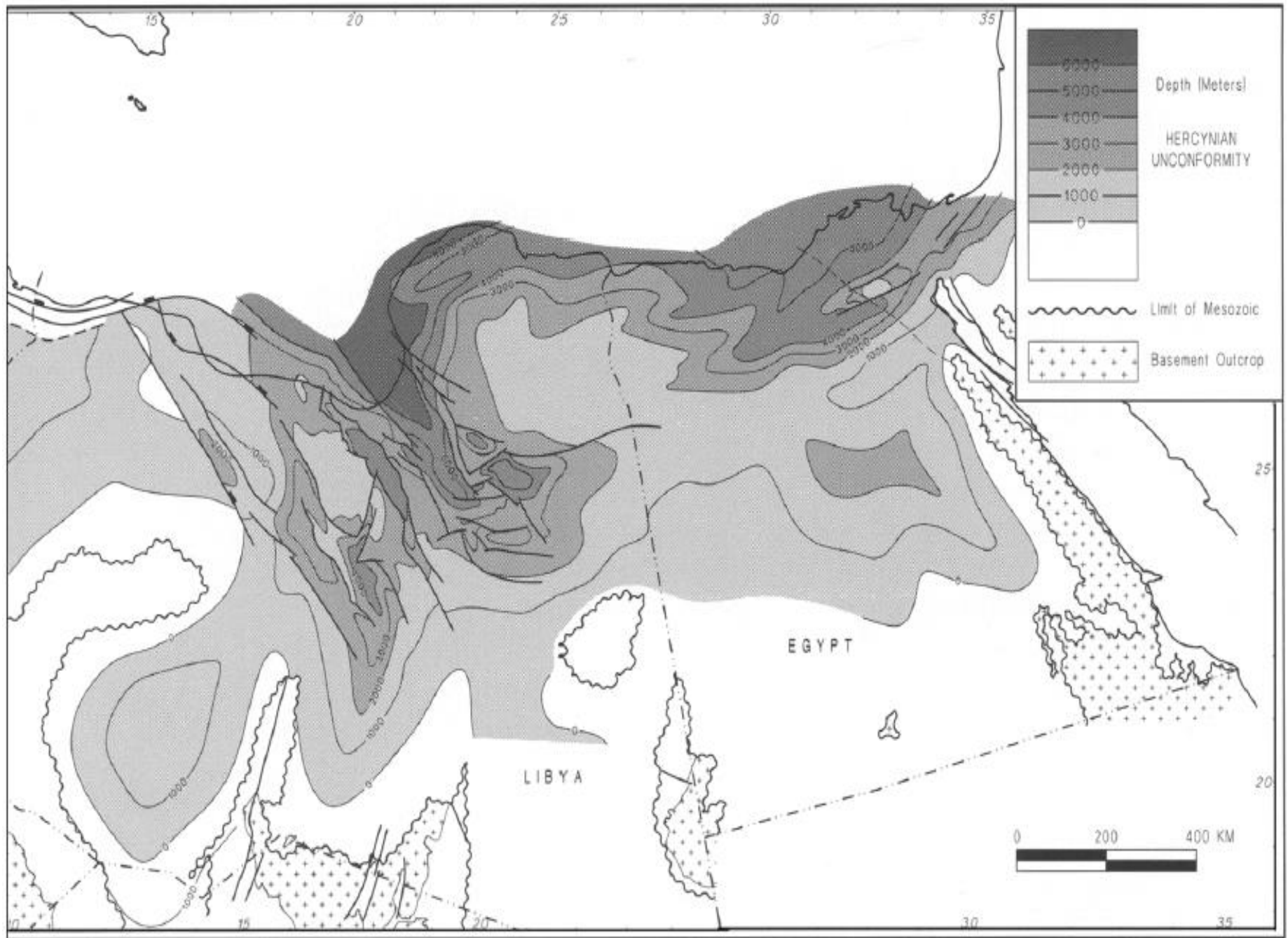


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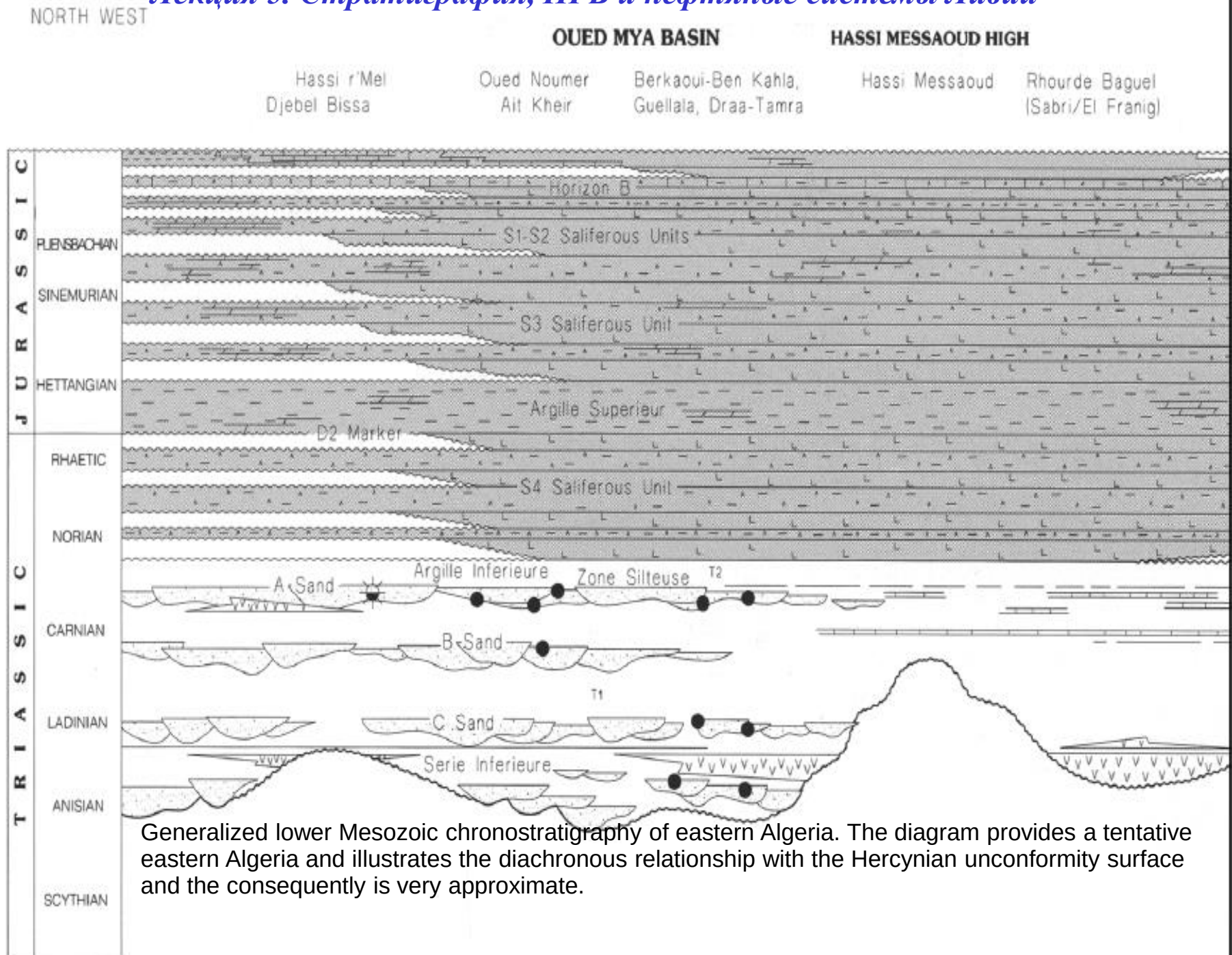


Generalized structure of Hercynian unconformity, highlighting the Mesozoic 'Triassic Basin' depocentre distribution of Palaeozoic basins on the North African Platform is a result of late Hercynian uplift and erosion of by later Mesozoic and early Tertiary subsidence associated with rifting and local transpression. Palaeozoic of Algeria and Cretaceous rift basins of Libya and Egypt

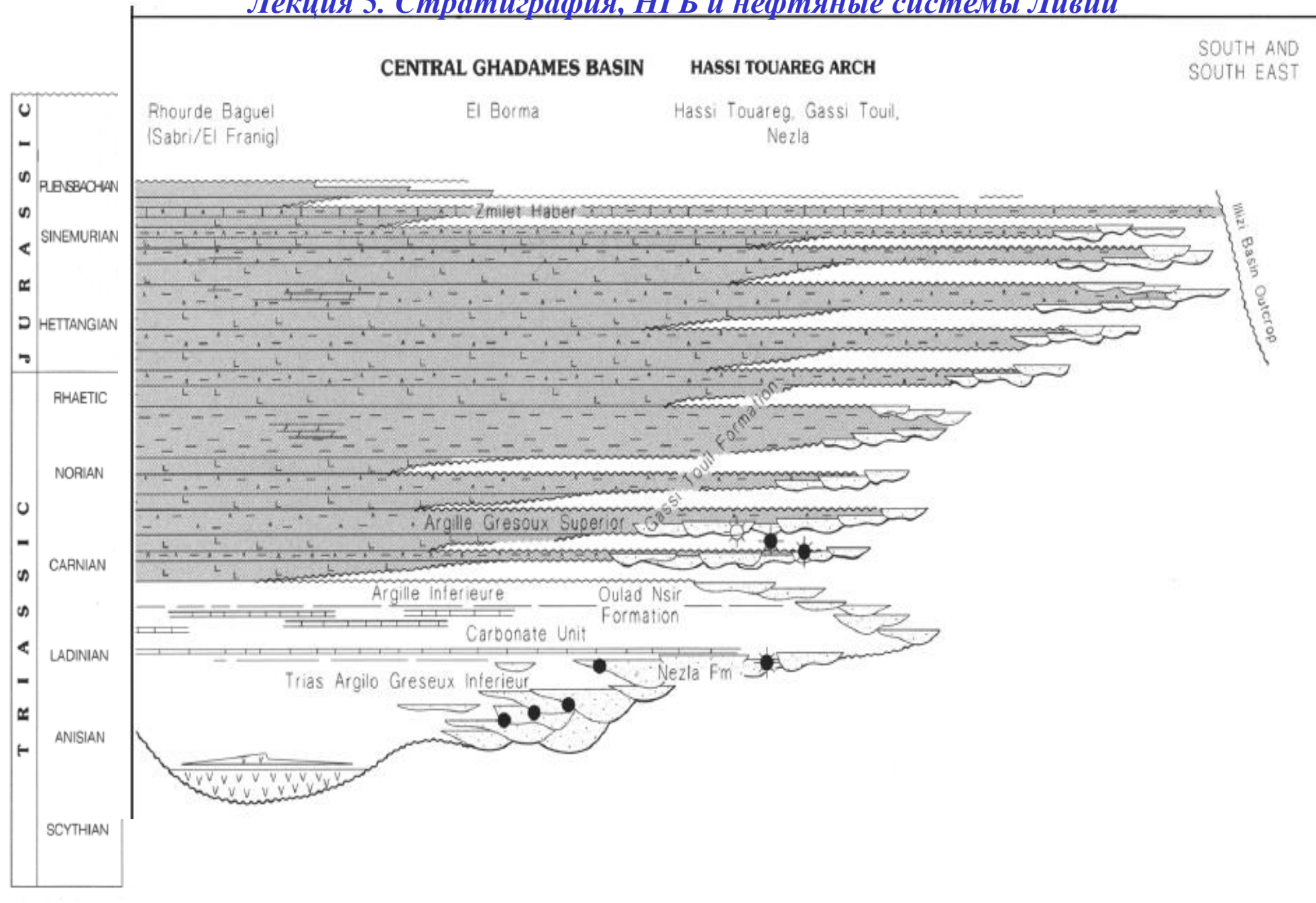
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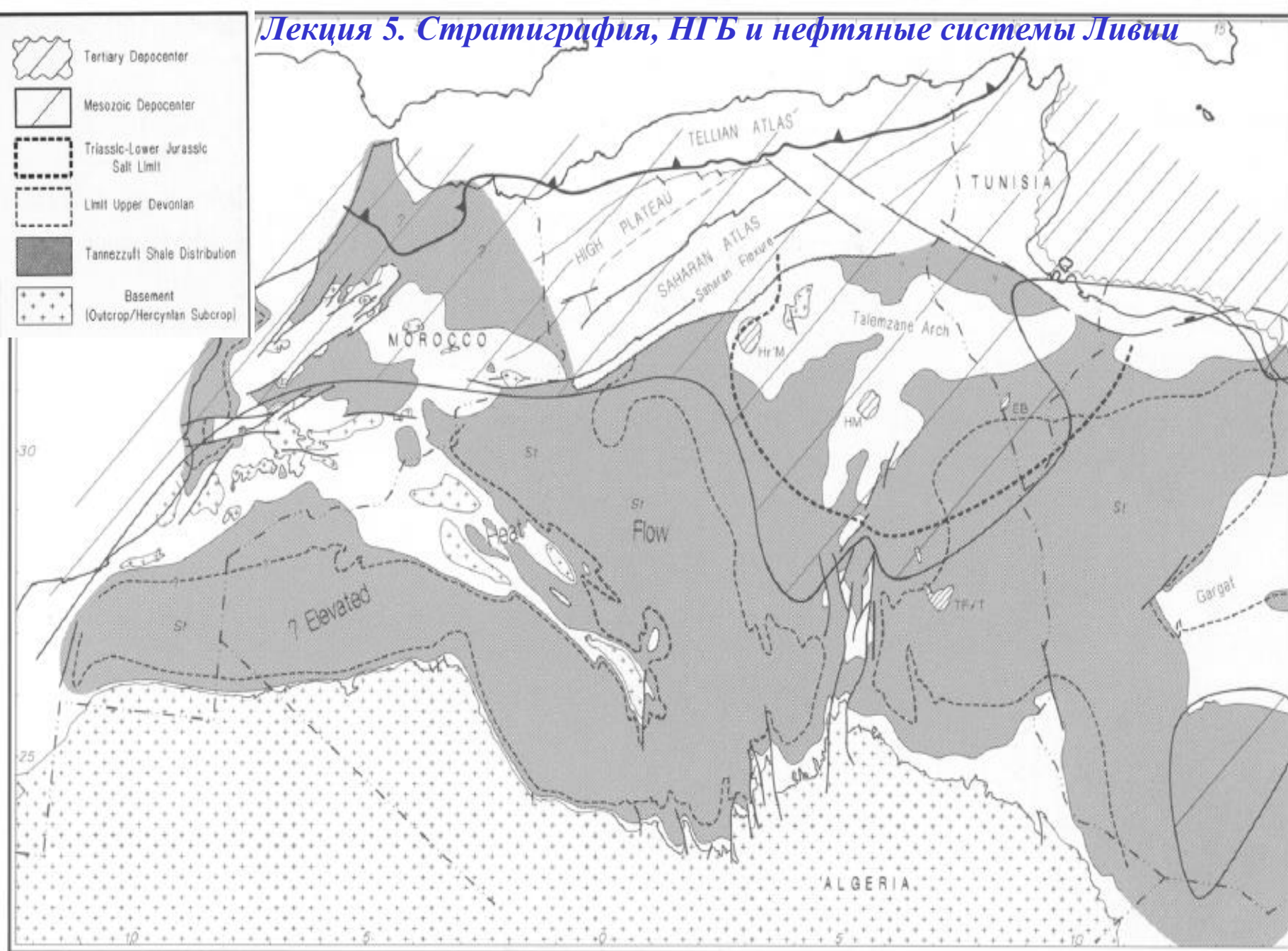
Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

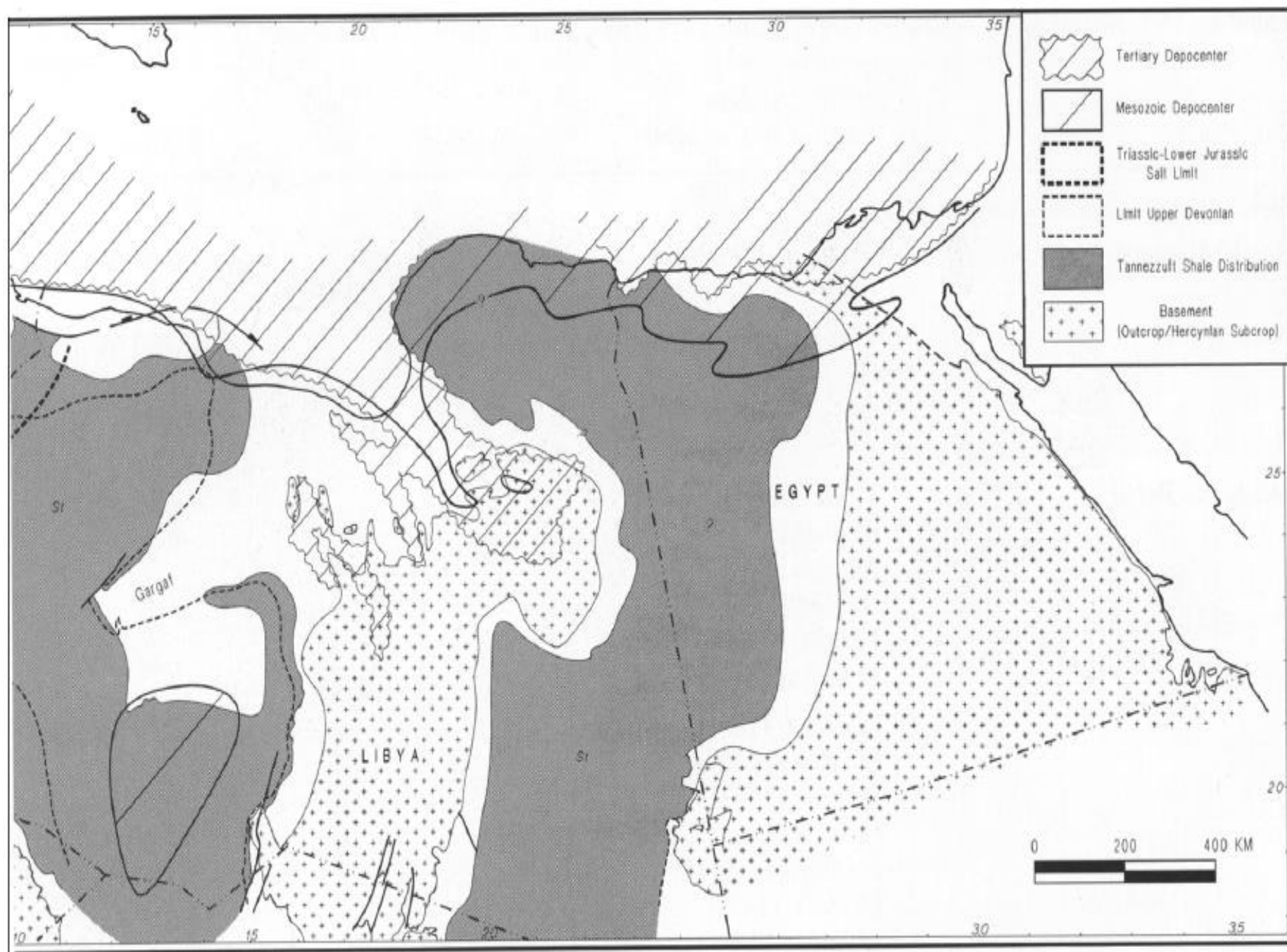


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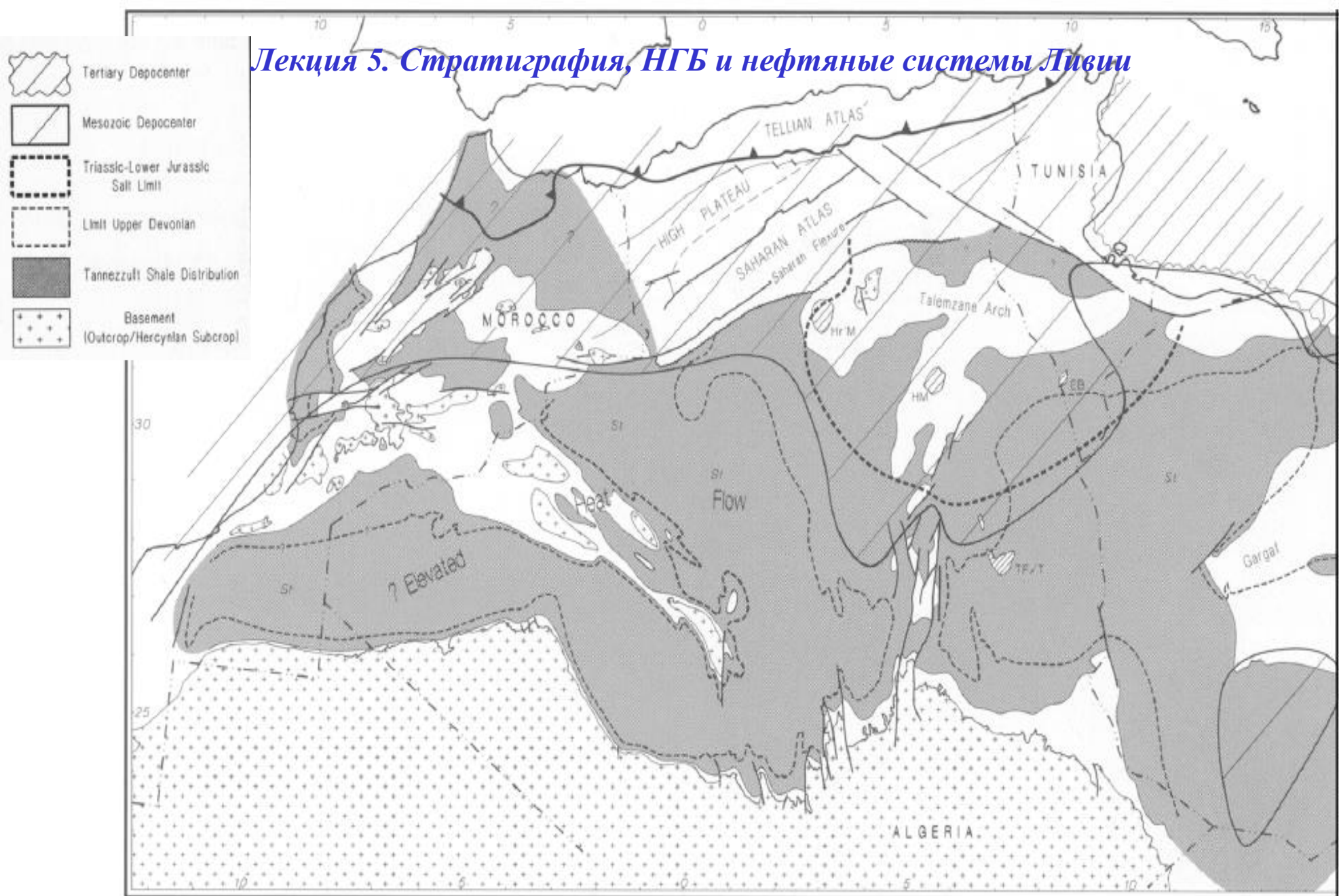


Regional stratigraphic and structural controls governing the distribution of Palaeozoic petroleum evaporite seals and areas of significant post-Hercynian subsidence are highlighted. With the exception of the Illizi strong positive correlation with these three factors. Pre-Hercynian petroleum systems were probably active in the thus generated were largely dispersed by late Hercynian uplift and unroofing

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии

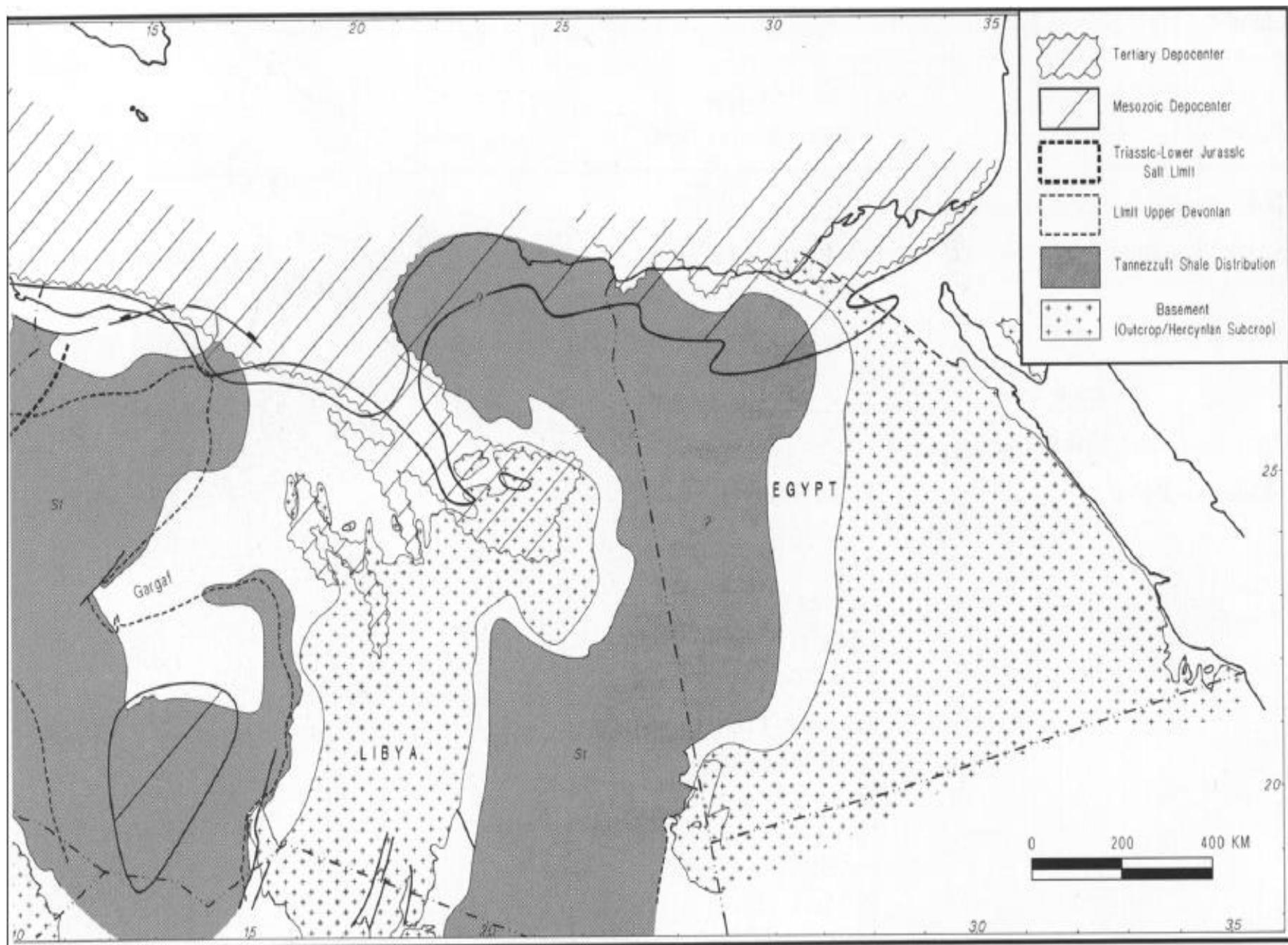


Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



Regional stratigraphic and structural controls governing the distribution of Palaeozoic petroleum evaporite seals and areas of significant post-Hercynian subsidence are highlighted. With the exception of the Illizi strong positive correlation with these three factors. Pre-Hercynian petroleum systems were probably active in the thus generated were largely dispersed by late Hercynian uplift and unroofing systems. The distribution of the Silurian Tanezzuft and Upper Devonian Frasnian source rocks, Triassic-Liassic Basin, which lacks Triassic reservoir and seal, all the high-productivity Palaeozoic systems of North Africa show a western and southwestern Palaeozoic basins, partly in response to regionally elevated heat flow.

Лекция 5. Стратиграфия, НГБ и нефтяные системы Ливии



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Evaporites, petroleum exploration, and the Cenozoic evolution of the Libyan shelf margin, central North Africa

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Phanerozoic geological evolution of Northern and Central Africa:
An overview

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