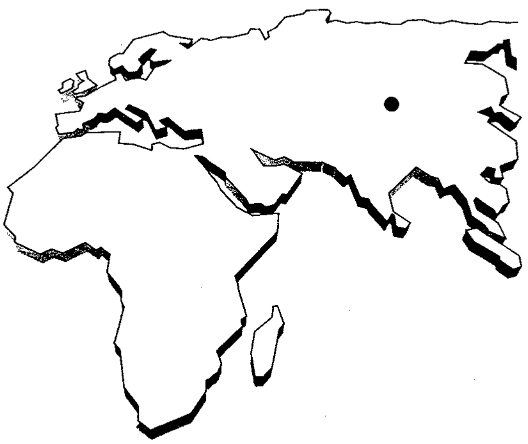
MAIN STAGES AND PALAEOGEOGRAPHY OF CENOZOIC SEDIMENTATION IN THE BAIKAL RIFT SYSTEM (EASTERN SIBERIA)

ÉTAPES PRINCIPALES ET PALÉOGÉOGRAPHIE DE LA SÉDIMENTATION CÉNOZOÏQUE DANS LE SYSTÈME DE RIFT DU BAÏKAL (SIBÉRIE ORIENTALE)

Serguei A. KASHIK and Vladimir N. MAZILOV



KASHIK, S.A. & MAZILOV, V.N. (1994). – Main stages and palaeogeography of Cenozoic sedimentation in the Baikal rift system (Eastern Siberia). [*Étapes principales et paléogéographie de la sédimentation cénozoïque dans le système de rift du Baïkal (Sibérie orientale)*]. – *Bull. Centres Rech. Explor.-Prod. Elf Aquitaine*, **18**, 2, 453-462, 7 fig.; Pau, December 26, 1994. – ISSN : 0396-2687. CODEN : BCREDP.

Les auteurs décrivent la stratégie, la sédimentologie et la paléogéographie du remplissage cénozoïque des bassins du système de rift de Sibérie orientale. Ils proposent un schéma régional de la stratigraphie des sédiments cénozoïques, avec une attention particulière pour les processus d'altération météorique. Ils reconnaissent trois phases sédimentaires qui diffèrent par leur contexte tectonique et leur cadre climatique.

A la limite Crétacé supérieur – Paléocène inférieur, les résidus latéritiques de l'altération se développent dans les montagnes de Sayan-Baïkal, en environnement tectonique stable, sous un climat chaud et humide.

Dans la deuxième phase, qui occupe la majeure partie du Paléocène et le Néogène inférieur, s'accumule une molasse à niveaux de charbon.

La troisième phase, qui commence au Pliocène et se poursuit actuellement, correspond à la sédimentation des bassins lacustres du Baïkal et du Khubsugul.

Serguei A. Kashik, Vladimir N. Mazilov, Institute of the Earth's Crust, Siberian Branch of the Russian Academy of Sciences, Lermontova Street 128, 664033 Irkutsk, Russia. – September 13, 1993.

Mots-clefs : Cénozoïque, Paléogéographie, Croûte altération (Paléoaltérite), Molasse, Rift Baïkal.

ABSTRACT

The stratigraphy, sedimentology and palaeogeography of the Cenozoic filling of the basins in the Eastern Siberia rift system are described. A regional scheme for the stratigraphy of the Cenozoic sediments is proposed with special attention being paid to the processes of ancient weathering. The sedimentation is divided into stages which differ in tectonic pattern and climatic conditions.

At the Late Cretaceous – Early Paleocene boundary, lateritic weathering residues were developing in the Sayan-Baikal highlands, in a stable tectonic environment under a warm moist climate.

During the second stage, through most of the Paleogene and Early Neogene, a coal-bearing molasse accumulated.

The third stage covers the deep-lake sedimentation in the Baikal and Khubsugul basins, which began in the Pliocene and is continuing at present.

Key words : Cenozoic, Palaeogeography, Crust (Palaeoalterite), Molasse, Baikal rift zone.

0396-2687/94/0018-0453 $ 1.80

CONTENTS — *TABLE DES MATIÈRES*

INTRODUCTION

The analysis of Cenozoic sedimentation in basins of the Eastern Siberia rift system, which extends to about 1 800 km on a NE-SW trend (Logatchev, 1993), makes it possible to decipher many distinctive features of rifting, to define the more important stages of the development of the present day relief (Fig. 1 and 2), and to show that, throughout the Cenozoic, there have been considerable changes in the climate of the Lake Baikal region. Many aspects of the lithology, stratigraphy, and palaeogeography of the Cenozoic sediments which infill the basins of the Eastern Siberia rift system (Fig. 2) have been covered by a number of papers over the last few decades. The purpose of this article is to summarize the most significant results and give an overview on the history of sedimentation during the Cenozoic.

1. — PRE-OROGENIC STAGE OF DEVELOPMENT (MAASTRICHTIAN-PALEOCNE)

During the Late Cretaceous-Early Paleocene, a relative stabilization of tectonic movements resulted in widespread peneplanation of the arched uplift in the Sayan-Baikal highlands with the development of a thick residue (Fig. 2 and 3) palaeosol on the deeply weathered surface (Logatchev, 1958; Florensov, 1960, 1968; Lamakin, 1960, 1961; Logatchev *et al.*, 1964; Logatchev, 1968, 1974).

1.1. CRETACEOUS-PALEOCENE WEATHERING RESIDUE

This surface has been deeply incised by erosion at the margins of intermontane basins and, at present, only fragments of it still survive. The relicts of the Cretaceous-Paleocene weathering residue are scattered over much of the Eastern Siberia rift zone – from Lake Khubsugul in the southwest to the Vitim plateau in the northeast. They are either buried under Paleogene-Neogene sediments in the basins, or are exposed on their flanks and on interbasin uplands. In detail, the distribution and morphology of the weathering residue are a function of the mineralogy and structure of the bedrock and the intensity of weathering. The thicker residue seems to be localized along basement fracture zones. Inevitably, the weathering residue is best known where exposed since, in the basins, it has been penetrated by only a few wells. For example, in the Tunka basin, only one well (near Khemchung village) reached the crystalline basement with traces of hypergene changes.

There are much more data on the weathering residues developed on basement highs within basins and on the interbasin highs. A 4-20 m thick residue occurs on the Elovsky and Nilovsky spurs of the Tunka basin and on the Alginsky spur of the Barguzin basin; typical residue occurs on the height separating the North and South Baikal basins, and between the South Baikal and Tunka, Maksimikha and Ust-Barguzin basins (Volkolakov & Khlystov, 1967; Dombrovskaya, 1973; Pavlov *et al.*, 1976).

A well-developed expanse of residue, locally up to 100 m thick, occurs on the southeast shore of Lake Baikal (from the Selenga delta to the southwest end of the lake, and also on the Khamar-Daban ridge, (Lamakin, 1960)). Numerous relicts of weathering residue also occur on the plateau surface of the Primorsky ridge (Fig. 2).

The most extensive remnants of weathering residues are exposed on the western shore of Olkhon island, which is a 150 × 30 km tectonic block (Logatchev, 1974). These represent the deeper parts of what was once a more extensive cover (Fig. 3).

There are much less data on the morphology and distribution of weathering residues in the northeastern branch of the Eastern Siberia rift system. Eluvial deposits (*Editor's note : weathered material at, or close to, its point of formation. Eluviation is the process of leaching in a soil, which mainly removes iron and calcium*) have been described. For example, on the South Muya ridges, in the Bambuiskaya, Upper Tsipa, Tuldun, Muya and Kalar intermontane basins, they were confirmed by drilling beneath Neogene or Pleistocene sediments, and also outcropping in the Chara and Olyokma rivers. However, their ages have not been determined and their composition has not been well studied.

1.2. CRETACEOUS-PALEOCENE SEDIMENTS

Contemporaneously with the formation of the weathering residues, depressions in the Cretaceous-Paleogene were filled with redeposited weathering products. These sediments have all the indications of being parautochthonous, suggesting that there was little significant relief at that time.

FIGURE 1

Location map of Lake Baikal.

Plan de position du lac Baïkal.

Cretaceous-Paleocene sediments have yet to be identified within the basins of the Eastern Siberia rift system. However, sediments of that period occurring on the northwestern and southeastern sides of the Baikal-Sayan highlands (*i.e.* on the flanks of the Pribaikalsky foredeep and the Eravninskaya basin) have been reliably dated by palynology (LITVINTSEV & TARAKANOVA, 1967; PAVLOV *et al.*, 1976. BELICHENKO *et al.*, 1962). There are thus grounds to suppose that similar sediments are also present in the larger rift basins (LOGATCHEV, 1974).

A sequence of immature Cretaceous-Paleogene sediments (which are the product of the weathering of basement crystalline rocks) interbedded with basalts and tuffs has been proved by drilling in the Tunka basin. It is 60 m thick but could be thicker towards the centre of the basin (see LOGATCHEV, 1993, for a cross section of the Tunka basin).

Thus in summary, during the Cretaceous to Paleocene, the Sayan-Baikal uplands suffered prolonged erosion and weathering with the peneplanation of the relief created during the Late Mesozoic orogeny (ERMIKOV, 1994), a weathered residue formation and the resedimentation of its products in shallow depressions on the erosion surface (LOGATCHEV, 1974).

1.3. MORPHO-CLIMATIC EVOLUTION

Palynological data indicates that the climate was moist and warm, similar to present tropical or sub-tropical conditions. The pollen microflora includes those from typical tropical plants such as *Proteacidites*, Loranthacea, *Aquila-*

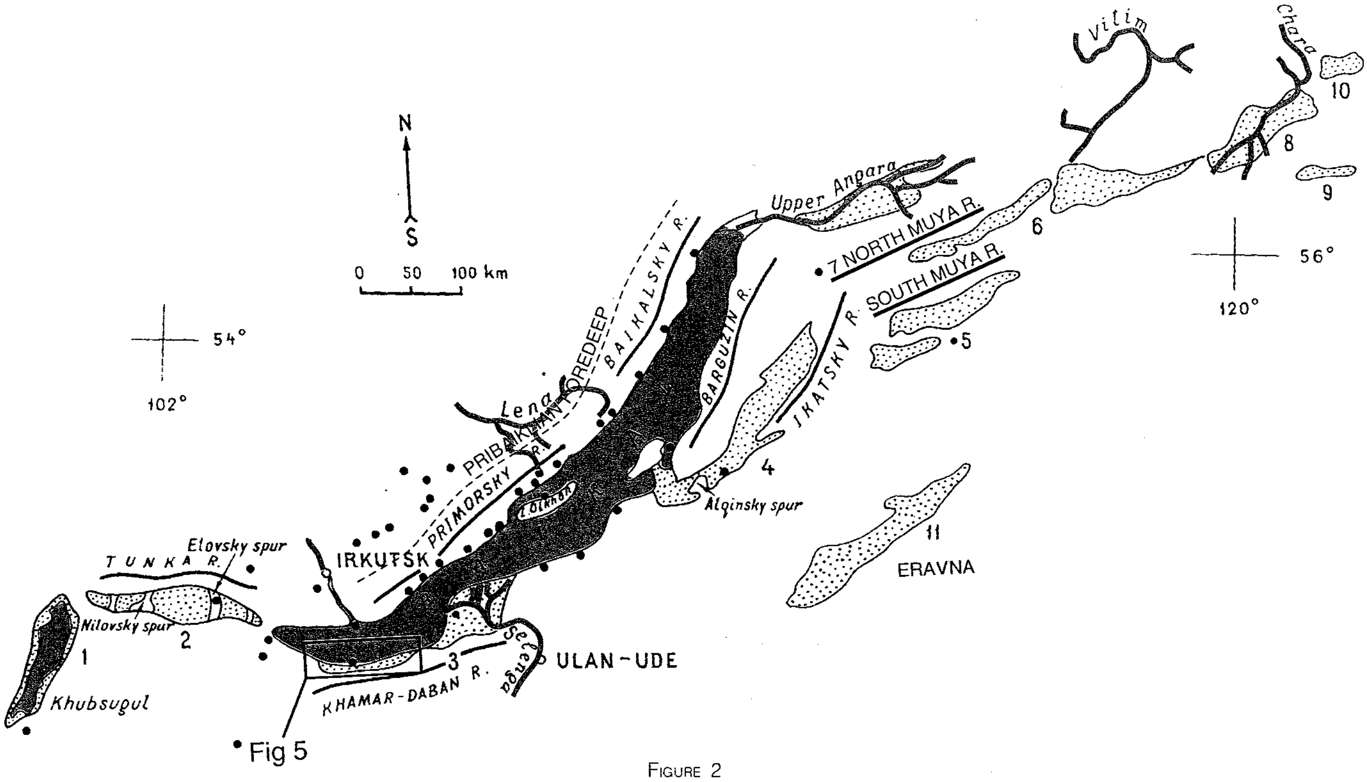


FIGURE 2

Main basins of the Cenozoic East Siberia rift system.
1 : Khubsugul; 2 : Tunka; 3 : South Baikal; 4 : Barguzin; 5 : Bauntov; 6 : Muya; 7 : Upper Angara; 8 : Chara; 9 : Kalar; 10 : Tokko; 11 : Eravna; dots : remnants of weathering residues.

Principaux bassins du système de rift cénozoïque de Sibérie orientale. Points : présence de résidus d'altération.

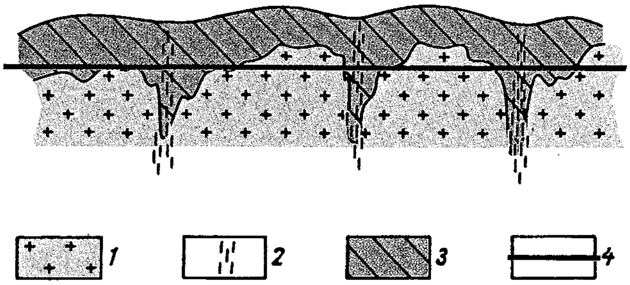


FIGURE 3

Cretaceous-Paleocene weathering residues on Olkhon Island.
1 : crystalline substratum; 2 : zones of tectonic fissures; 3 : probable maximum extension of the weathering residues; 4 : present surface with "roots" of weathering residues.

Résidus d'altération sur l'île d'Olkhon.
1 : Substratum cristallin; 2 : zones de fissures tectoniques; 3 : extension maximale probable des résidus d'altération; 4 : surface actuelle avec les « racines » de résidus d'altération.

pollenites and *Parviprojectus* (PAVLOV, 1976). Though these forms were encountered in deposits outside the Eastern Siberia rift basins, but in the Cretaceous to Paleocene deposits of the Pribaikalian foredeep, it is unlikely that the climatic conditions were significantly different within the adjacent rifts. This is supported by the pollens recovered from the Eocene deposits and proved by drilling in the South Baikal basin, which are from palms, myrtles, araucarias and wax-myrtles (LOGATCHEV, 1972).

The chemical composition of the Cretaceous-Paleocene weathering residues is rather homogeneous despite the heterogeneity of its substratum. Almost everywhere, the upper zone of the alteration profile is composed of kaolinite, but in some cases, for example below the Oligocene-Miocene brown coal deposits in the Tunka basin, much of it is of gibbsite. Deposits of typical lateritic bauxites are known in the Pribaikalian foredeep, *i.e.* close to the Baikal rift zone, and thus it is possible that analogous formations could be found within the rift basins. In terms of facies, the Cretaceous-Paleocene sediments are represented by eluvial, flood and torrential out-wash deposits, intercalated with locally derived fluviatile and shallow lake deposits.

2. — EARLY OROGENIC STAGE OF DEVELOPMENT (EOCENE-MIOCENE)

2.1. EOCENE DEPOSITS

Wide shallow basins rather than deep rift basins were formed in the Eocene. Eocene deposits in the Eastern Siberia rift system are only found in the area of the Selenga river delta, where a well still reached TD in Cenozoic

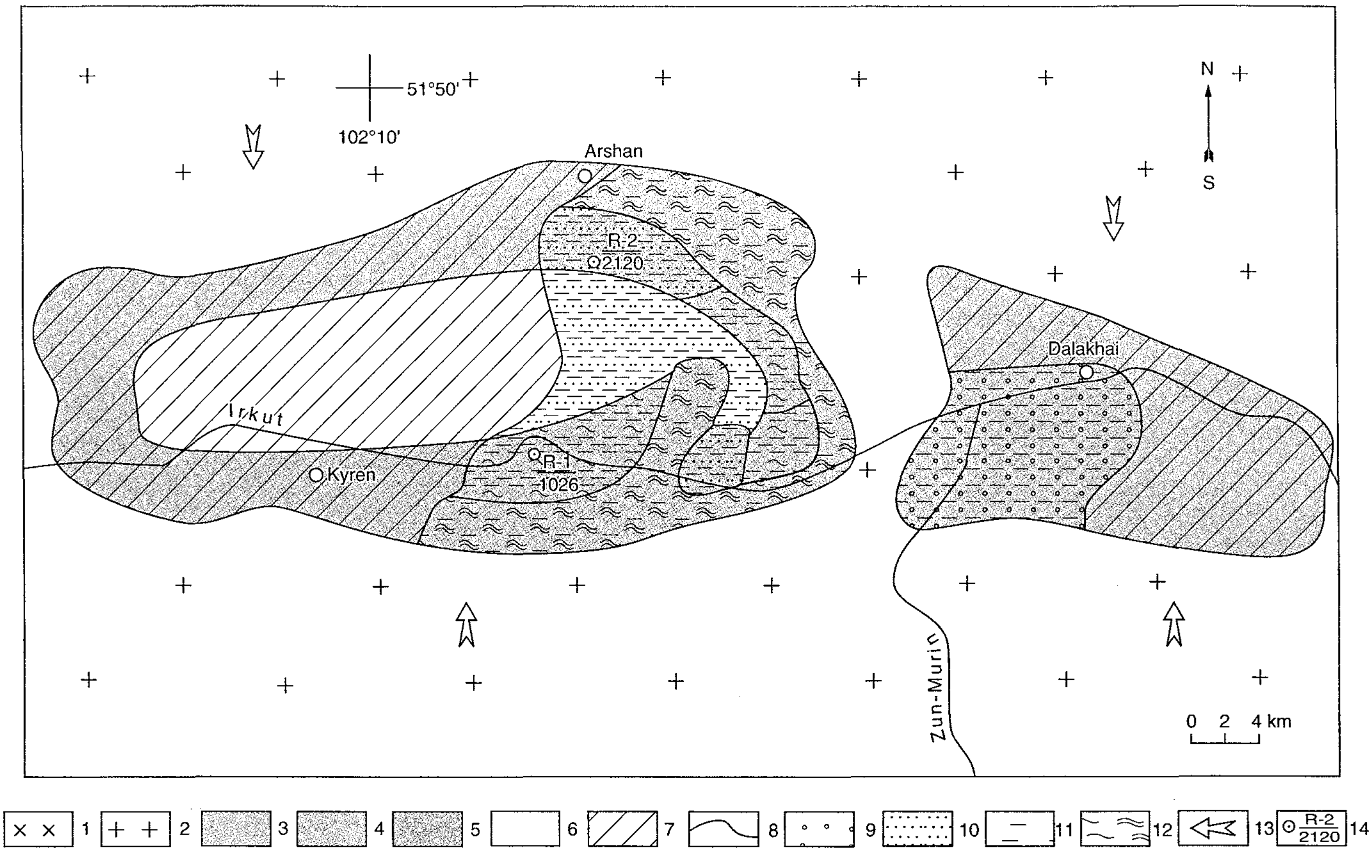


FIGURE 4

Late Oligocene – Early Miocene of the Tunka basin : lithology and facies inferred from borehole and mine information.
1 : area of erosion with high relief; 2 : area of erosion with low relief; 3 : channel facies with coarse-grained sediments; 4 : swamp-lacustrine facies with rare alluvial facies; 5 : lacustrine sediments; 6 : lacustrine facies alternating with fluviatile facies; 7 : inferred extension of Late Oligocene – Early Miocene series below Quaternary sediments (based on boreholes); 8 : facies limit; 9 : conglomerates; 10 : sands and sandstones; 11 : siltstones; 12 : clays; 13 : direction of transport (Eocene – Pleistocene); 14 : borehole and TD.

Oligocène supérieur – Miocène inférieur du bassin de Tunka : lithologie et faciès déduits des données de forages et minières. 1 : zone d'érosion à haut relief; 2 : zone d'érosion à relief bas; 3 : faciès de chennaux à sédiments grossiers; 4 : faciès de marais lacustre avec de rares faciès alluviaux; 5 : sédiments lacustres; 6 : alternance de sédiments lacustres et fluviatiles; 7 : extension supposée de la série Oligocène supérieur – Miocène inférieur sous les sédiments quaternaires (déduite des données de forages); 8 : limites de faciès; 9 : conglomérats; 10 : sables et grès; 11 : grès fins; 12 : argiles; 13 : direction de transports (Éocène-Pléistocène); 14 : forages et profondeurs finales.

deposits at 3 100 m. Note that, due to the rarity of samples, it is impossible either to define the stratigraphic tops or give a detailed facies analysis. However, the probable Eocene comprises mainly siltstones, shales and clays with intercalations of clayey and sandy limestones, marls and brown coal. Locally, sandstones, some coarse-grained and pebbly, and conglomerates occur. Palynological samples between 1 700-2 500 m show a predominance of Pteridophyte spores. Pollen of subtropical evergreen forms such as myrtles, *Myrica*, sumac, *Magnolia* and palms, etc. are common.

Eocene deposits may also extend to the northeast end of the Baikal basin where, according to gravimetry data (ZORIN, 1971), the Cenozoic section could be about 4 000 m thick. They could also extend to the Tunka basin where the crystalline basement is estimated to be 2 500 m deep.

As the other basins in the Eastern Siberia rift system are less than 2 000 m deep, it is inferred that an Eocene section is probably absent. Evidently, the deepest basins are the earliest. Thus, only a few depressions – the foci of alluvial-lacustrine deposits, in the Pribaikalian low relief – may have originated in the Eocene. The main "nuclei" of the present Baikal depression were the South and North Baikal basins, at the ends of which younger rift basins developed. These were exposed during the following early orogenic period, from the Oligocene to Early Pliocene (LOGATCHEV, 1974). In other more stable areas, kaolinitic and lateritic weathering residues continued to form.

2.2. OLIGOCENE-MIOCENE COAL-BEARING MOLASSE

During the Oligocene and Miocene, coal-bearing molasse sediments related to an early orogenic stage were deposited (LOGATCHEV, 1968). Their thickness range from 1 000 – 2 500 m, the maximum being in the Tunka (Fig. 4) and the South Baikal basin (Fig. 5). Rapid facies changes between fluviatile, swampy and lacustrine deposits, occur along the strike of the rift (Fig. 4 and 5).

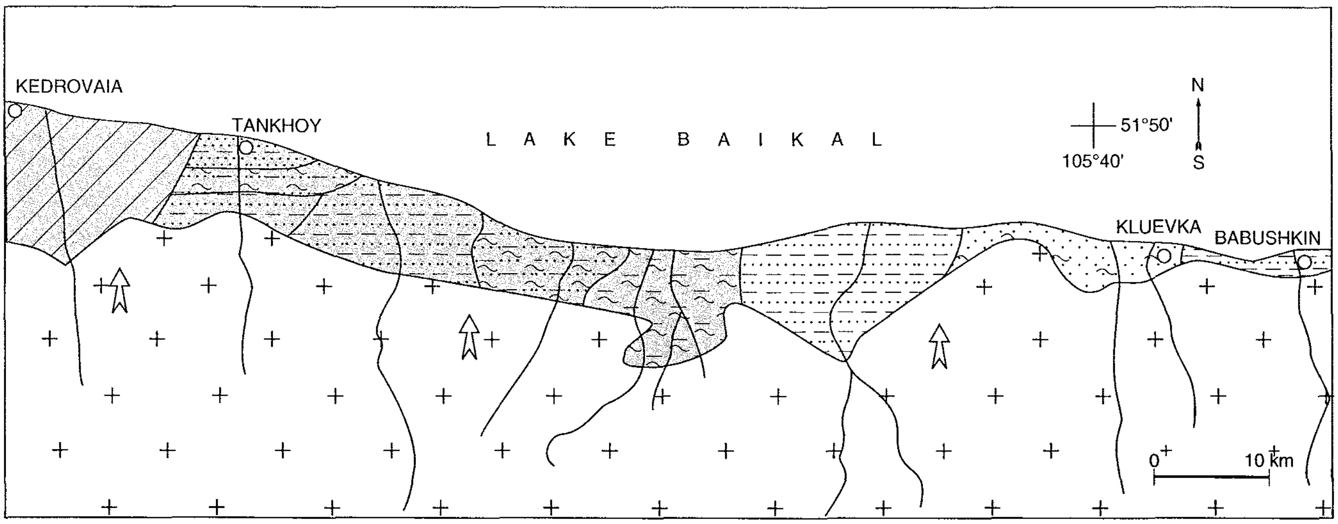


FIGURE 5

Late Oligocene – Early Miocene of the southeast coast of Lake Baikal including the Tankhoy coal field. Lithology and facies inferred from borehole and mine information (for legend, see Fig. 4).

Oligocène supérieur – Miocène inférieur de la côte sud-ouest du lac Baïkal comprenant le bassin houiller de Tankhoy. Lithologies et faciès déduits des données de forages et minières (pour la légende, voir Fig. 4).

Alluvial-fan deposits, typical of basins within a high-relief framework, are rare, occurring only on Olkhon Island, Priolkhonye and in the Tankhoy coal-bearing field (located on the southeast coast of Lake Baikal (Fig. 5)). At these locations, coarse detritics are absent. Only angular and sub-angular arkosic sands which occurr are in a clay matrix. The only Miocene fossils known in the Pribaikalye and Trans-Baikal areas occur in this facies on Olkhon Island (LOGATCHEV *et al.*, 1964).

Lithologically, the series is composed of mainly sandstones, silstones and clays with rare gravels and pebbly conglomerates. Sands, siltstones and clays alternate with no obvious rhythm. Siltstones generally predominate but in some cases, e.g. in the Tunka basin, clays predominate and sandstones are rare. The coarse detritics mark the location of river channels, deltas and shorelines of ancient lakes. This facies has been found up to 3 m thick in the subsurface, for example beneath the present Selenga delta. Intercalations and lenses of more or less argillaceous dolomites, limestones and marls are relatively rare.

In the Tunka, South Baikal and Barguzin basins, brown coal seams are common, some being up to 30 m thick (on the Elovsky spur of the Tunka basin). Well-developed basaltic lava flows also occur in the Tunka basin (LOGATCHEV & KRAVTCHENKO, 1955).

An important feature of the coal-bearing molasse is the relative constancy of the grain-size over wide areas which indicates that the facies bear no relation with the observed structural-morphological margins of the present basins. It is thus inferred that the present margins do not correspond to the genetic contours and margins of the palaeo-basins. The Oligocene-Miocene fine-grained coal-bearing deposits of the Tankhoy field, Tunka basin (Elovsky spur) and Barguzin basin (Alginsky spur) are located close to high mountain slopes of the Khamar-Daban, Tunka and Ikatsky ridges respectively. Undoubtedly, these formations originated from geomorphological conditions which were very different from the present ones, both in terms of area of deposition and the height of adjacent relief. The original area of deposition of the fine-grained coal-bearing deposits was probably much wider than their present distribution.

During the Eocene-Miocene the surface of the basins was occupied by a number of shallow lakes linked by a complex channel system. In most of the basins, subsidence was compensated by the accumulation of terrigenous sediments thus favouring coal formation. The lakes were of limited extension as indicated by the extensive fluviatile facies. This is supported by the study of diatoms from the Tunka basin (CHEREMISINOVA, 1973) which showed that a number of shallow eutrophic lakes existed there in the Miocene. The lakes were up to 40 km wide and up to 100 km long. These were linked by anastomosed channels. Swampy facies developed from time to time at the lake peripheries. The depth of the lakes was mainly between 20-30 m, but locally they were up to 200 m deep. Alluvial deposits were restricted to the area around the present Zun-Murin river (Fig. 4).

In the South and North Baikal basins, trough subsidence was so rapid that compensatory deposition could not keep up. POPOVA (1971) shows, from the analysis of the rich malacofauna (*Parunio, Aculticosta, Cuneopsis, Nepponiheria, Lepidodesma,* etc.) in the Selenga well, that, during the Oligo-Miocene, there was a large freshwater lake which was between 40 and 150 m deep at the site of the present South Baikal basin. Its temperature and hydrological regime is interpreted as being similar to present-day deep-water lakes in the subtropical zone. The salinity was up to 500 mg/l. This is an obvious explanation of the encountered carbonate layers. There was a limited development of peat bogs, while alluvial deposits predominated (Fig. 5).

2.3. MORPHO-CLIMATIC EVOLUTION

Thus, in an early orogenic development stage during the Oligocene-Miocene, the Sayan-Baikal uplands were subjected to a slow arching uplift which rose several hundred metres above the adjacent plain of the Siberian platform. At the same time the arch began to differentiate with local downwarps, which were filled in with resedimented products of weathering in a sub-tropical climate, in a fluviatile and limnic environment (Logatchev, 1972). Many of these downwarps later turned into rift basins.

3. — LATE-OROGENIC STAGE OF DEVELOPMENT (PLIOCENE-PLEISTOCENE)

During the Pliocene, a general increase in the rate of vertical movements led to the formation of a complex of horsts and grabens in the Eastern Siberia rift zone. At the same time, climatic changes occurred, with a lowering of the mean temperature and a more continental, drier climate. Palynological data indicate that there was firstly a decrease in the number of sub-tropical moisture and heat-loving flora and wide-leaf species, and then that they completely disappeared. This was followed by a gradual increase in the taiga-zone type flora (Pavlov *et al.*, 1972). Inevitably this climate change is reflected in the nature of sediments deposited during the Pliocene.

Under the influence of an increasing rate and amplitude of tectonic movements, the detritics were coarse (contrasting sharply with the underlying Tankhoy fine-grained sediments). Thus, the new orogenic stage of development is the accumulation of typical molasse – thick coarse detritics, which is restricted within the present limits of all the rift basins.

3.1. PLIOCENE ANOSOV "OCHRE" SUITE

In the South Baikal basin, the Pliocene is represented by deposits of the Anosov suite (Logatchev *et al.*, 1964), composed of conglomerates, gravelstones, sandstones and siltstones which fine away from the basin periphery. Analogous sediments are also present in the Tunka basin and in the North Baikal basin (Bazarov, 1986). In the Barguzin basin the Pliocene deposits are predominantly of ochre sand-clay but they also grade to gravelstones and conglomerates towards the Barguzin ridge (Florensov, 1960).

The Pliocene series shows a variety of continental facies including lacustrine, fluviatile, alluvial, torrential and flood facies (the latter covering proluvial, deluvial and collapse-talus). The distribution of facies in the Upper Pliocene of the Tunka basin shows fining away from the northern edge of the basin, from channel coarse-grained deposits to fluviatile and finally fine-grained lacustrine sediments (Fig. 6).

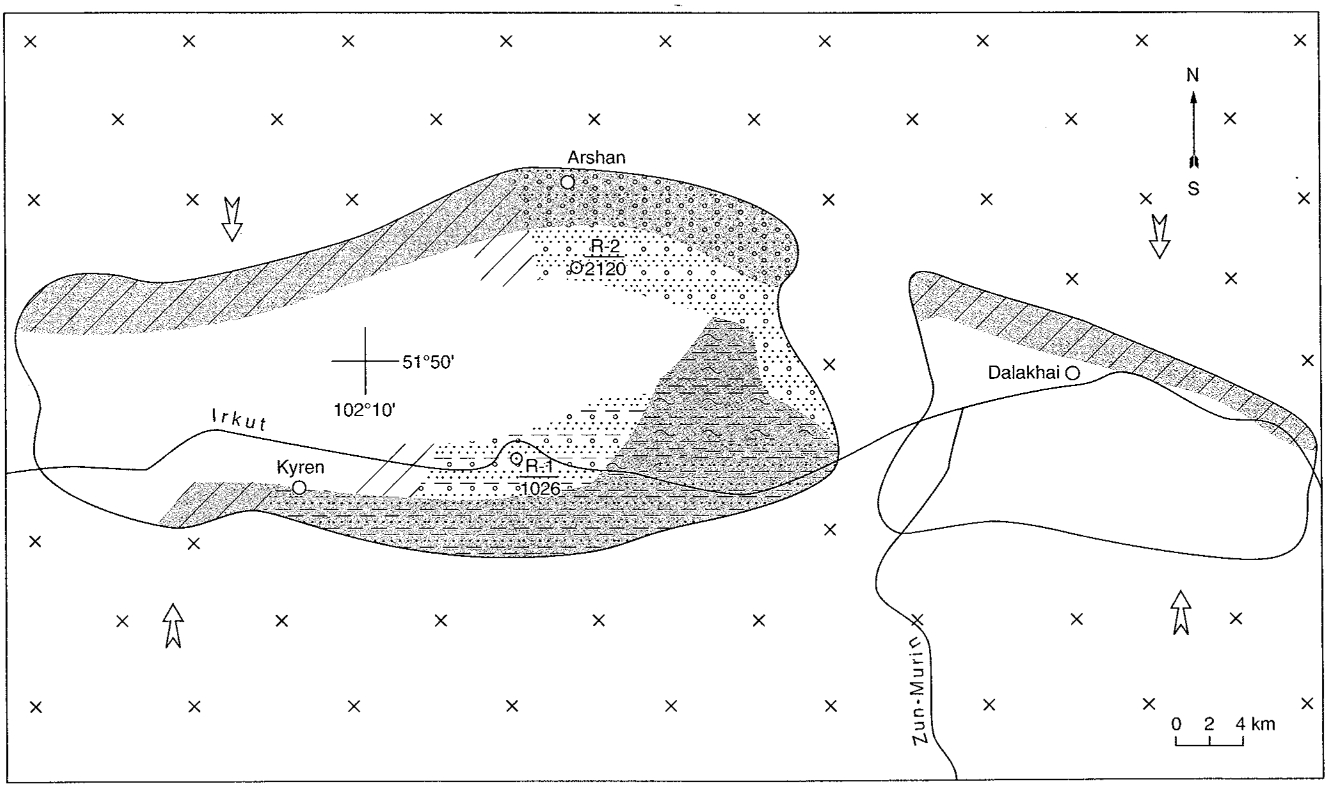


Figure 6

Late Pliocene of the Tunka basin. Lithology and facies inferred from borehole information (for legend, see Fig. 4).

Pliocène supérieur du bassin de Tunka. Lithologies et faciès déduits des données de forages (pour les légendes, voir Fig. 4).

The clasts from the boulders to the silt are generally polymictic, poorly-rounded and sorted. Well-sorted sediments are rare even among the subaqueous facies. Thus the deposits are essentially proximal from the immediately adjacent mountain uplands, though there are indications of some axial transport.

All the Pliocene deposits show characteristic ferric hydroxide crusts and concretions, from which the original name "ochre" comes (LOGATCHEV, 1958). The distribution of 'ochre' is not uniform. The Pliocene of the Tunka basin has the greatest concentration while in the South Baikal and Barguzin, it has the least. LOGATCHEV *et al.* (1964) also identified a greater proportion of reworking and resedimentation of the iron-rich residues where it was originally more concentrated.

3.2. LATE PLIOCENE – EARLY PLEISTOCENE EXPLOSIVE VOLCANIC PHASE

In the Late Pliocene – Early Pleistocene, violent explosive volcanism occurred on the western flank of the Eastern Siberia rift zone. The activity was particularly strong in the Tunka basin where it resulted in a 200 m (maximum) thick pyroclastic unit comprising alkaline tuffs, tuffites and tuff-sandstones which interfinger into the sandy and silty sediments towards the basin periphery.

3.3. UPPER LATE OROGENIC FORMATIONS

The upper late orogenic formation comprises a grey sandy molasse (LOGATCHEV, 1958, 1968) which displays many features similar to the lower "ochre" molasse. It is essentially polymictic and shows rapid variations of lateral facies.

The upper 300-400 m thick unit which is composed of polimictic sands and sandy loam covers about half the area of the Cenozoic basins in the Eastern Siberia rift system – the Tunka, Barguzin, Upper Angara, Muya and Chara basins. The presence of well-developed cryogenic structures [e.g. solifluction features] and fossils of cold-resistant fauna and flora suggest that these are periglacial deposits in an intramontane environment (LOGATCHEV, 1958, 1968).

3.4. MORPHO-CLIMATIC EVOLUTION

The late orogenic stage embraces about 3-4 million years of geological history and is divided into two stages. The earlier one, which lasted from the beginning of glaciation, relates to the formation of important modern morphostructural features of the Sayan-Baikal uplands and its boundaries with the adjacent morphostructural zones of the Siberian platform and the Trans-Baikal area. The last stage relates to the Pleistocene with its glacial and periglacial conditions and is continuing at present.

4. — CONCLUSIONS

Three stages in the Cenozoic sedimentation history can be distinguished, each with its own tectonic regime and characteristic sedimentation : Cretaceous-Paleocene, Eocene-Miocene, and Pliocene-Pleistocene.

During the Cretaceous-Paleocene, weathering residues, either kaolinitic or lateritic, developed over the vast area of the present Sayan-Baikal uplands, in an environment of stable tectonics and a warm, moist climate. Sedimentation was localized in shallow depressions where only locally-derived material was deposited.

The second stage, during the Eocene-Miocene, also showed little tectonic activity, with the deposition of limnic sediments under sub-tropical conditions in smooth low relief. Long-wavelength sags were precursors to (but probably wider than) the later rift basins.

The third stage during the Pliocene-Pleistocene was accompanied by a decrease in the mean annual temperature and the development of mountain-taiga and steppe landscape. Strong vertical movements were reflected by the general uplift of the Baikal mountain area and the marked subsidence which was localized within the rift basins, particularly in the Baikal rift where the subsidence outstripped sedimentation and deep lakes were formed (Fig. 7). The nature of the sedimentation which was of alluvial and periglacial fan facies, and the intensity of the vertical movements did not change throughout the Pleistocene.

The duration of the Holocene is so short that it has not proved possible to characterize the sedimentation and tectonic movements adequately. In general, the area under consideration is developing in the same way as it has done since the Pliocene.

Acknowledgements

The authors express their gratitude to Academician N.A. LOGATCHEV for his valuable advice, for his editing of the manuscript and his amiable permission to use the results of his extensive studies during the writing of the paper. The authors are also grateful to the Russian Fund of Fundamental Studies for supporting their research with grant N° 93-05-9994.

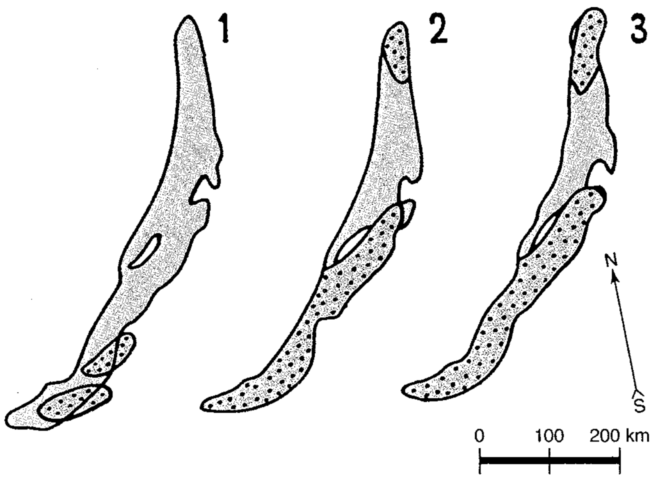


FIGURE 7

Palaeo-lakes in the Baikal basin (from FLORENSOV *et al.*, 1982).
1 : Late Oligocene – Early Miocene; 2 : Late Pliocene;
3 : Early – Middle Pleistocene.

Paléo-lacs du bassin du Baïkal (d'après FLORENSOV et al., *1982).*
1 : Oligocène supérieur – Miocène inférieur; 2 : Pliocène supérieur; 3 : Pléistocène inférieur à moyen.

5. — REFERENCES

BAZAROV, D.D.B. (1986). — The Cenozoic of Pribaikalye and Trans-Baikal western area. — Nauka, Novosibirsk, 180 pp. (in Russian).

BELITCHENKO, V.G., KOMAROV, Y.V., MUSIN, Y.B., KHRENOV, P.M. & CHARNOV, Y.A. (1962). — Geological-petrographical outline of the south margin of the Vitim plateau. — *Izv. Akad. Nauk USSR*, 168 pp. (in Russian).

CHEREMISINOVA, E.A. (1973). — Diatomaceous flora of the Neogene sediments in Pribaikalye. — Nauka, Novosibirsk, 68 pp. (in Russian).

DOMBROVSKAYA, E.A. (1973). — Ancient weathering crust of the Pribaikalye. — *In* : SAPZHNIKOV, D.G. (ed.) : Weathering crust. — Nauka, Moscow, **11**, 127-138 (in Russian).

DOMBROVSKAYA, E.A. (1973). — Paleogene weathering crust of the Central Pribaikalye. — Nauka, Moscow, 155 pp. (in Russian).

ERMIKOV, V.D. (1994). — Mesozoic precursors of rift structures of Central Asia. — *Bull. Centres Rech. Explor.-Prod. Elf Aquitaine*, **18**, 1, 123-134.

FLORENSOV, N.A. (1960). — Mesozoic and Cenozoic depressions of Pribaikalye. — *Izv. Akad. Nauk USSR*, 258 pp. (in Russian).

FLORENSOV, N.A. (1968). — The Baikal rift zone and some problems of its study. — *In :* FLORENSOV, N.A. (ed.) : The Baikal rift. — Nauka, Moscow, 40-56 (in Russian).

FLORENSOV, N.A., LUT, B.F., BELOVA, V.A. & GOLDYREV, G.S. (1982). — Evolution of the Baikal Basin. — *Trudy Limnol. Inst.*, **40**, 6-11 (in Russian).

LAMAKIN, V.V. (1960). — The geological history of the Pribaikalian peneplain. — *Bull. Comm. study Quatern.*, **24**, 129-133.

LITVINTSEV, G.G. & TARAKANOVA, G.I. (1967). — Lithological and palinological characteristics of the Upper Cretaceous and Paleogene deposits in western Pribaikalye. — *In* : FLORENSOV, N.A. (ed.) : The Mesozoic and Cenozoic stratigraphy of Siberia. — Nauka, Moscow, 123-138 (in Russian).

LOGATCHEV, N.A. (1958). — Cenozoic continental sediments from the Baikal type basins. — *Izv. Akad. Nauk USSR*, **4**, 18-29 (in Russian).

LOGATCHEV, N.A. (1968). — Sedimentary and volcanologenic formations of the Baikal rift zone.— *In* : FLORENSOV, N.A. (ed.) : The Baikal rift. — Nauka, Moscow, 72-101 (in Russian).

LOGATCHEV, N.A. (1972). — Lithology of the Tertiary deposits of the south-western part of the Baikal rift zone. — Nauka, Moscow, 120 pp. (in Russian).

LOGATCHEV, N.A. (1974). — Relief and geomorphological regionalization. *In* : FLORENSOV, N.A. (ed.) : The uplands of Pribaikalye and Trans-Baikal. — Nauka, Moscow, 16-159 (in Russian).

LOGATCHEV, N.A. (1993). — History and geodynamics of the Lake Baikal rift in the context of the Eastern Siberia rift system : a review. — *Bull. Centres Rech. Explor.-Prod. Elf Aquitaine*, **17, 2, 353-370.**

LOGATCHEV, N.A. & KRAVTCHENKO, E.V. (1955). — The location of basalts in the Tunka basin. — *Dokl. Akad. Nauk SSSR*, **104**, 3, 723-726 (in Russian).

LOGATCHEV, N.A., LOMONOSOVA, T.K. & KLIMANOVA, V.M. (1964). — Cenozoic sediments of the Irkutsk pit. — Nauka, Moscow, 194 pp. (in Russian).

PAVLOV, S.F., KASHIK, S.A., LOMONOSOVA, T.K., MAZILOV, V.P., KLIMANOVA, V.M. & RYBAKOV, V.G. (1976). — Cenozoic weathering crusts and sedimentary rocks of the Western Pribaikalye. — Nauka, Novosibirsk, 160 pp. (in Russian).

POPOVA, S.M. (1971). — Cenozoic continental mollusks of the South Siberia and Far East. — *Geol. Geophys.*, **6**, 53-61 (in Russian).

VOLKOLAKOV, F.K. & KHLYSTOV, P.A. (1967). — On hydrargillite content in the Paleogene (?) weathering crust of Tunka basin. — *In* : SHABOGOROV, P.I. (ed.) : Materials on geology and minerals of the Buryat Republic. — Ulan-Ude, **11**, 51-53 (in Russian).

ZORIN, Y.A. (1971). — The neotectonic structure and isostacy of the Baikal rift zone. — Nauka, Moscow, 232 pp. (in Russian).