MESOZOIC PRECURSORS OF THE CENOZOIC RIFT STRUCTURES OF CENTRAL ASIA

PRÉCURSEURS MÉSOZOÏQUES DES STRUCTURES DE RIFTS CÉNOZOÏQUES D'ASIE CENTRALE

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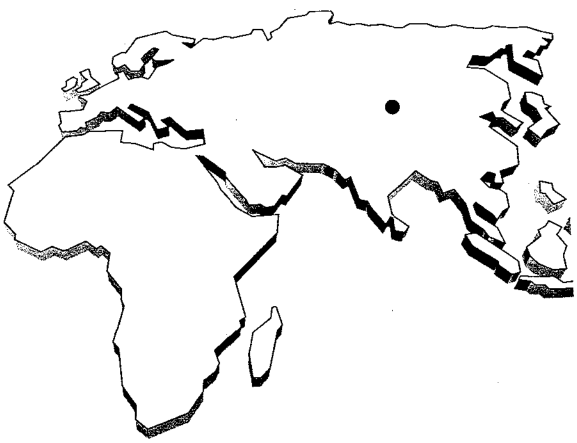

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Sur la ceinture montagneuse d'Asie Centrale qui s'étend sur 5 000 km de long et 1 000 km de large, s'est installé le système de rift cénozoïque de Sibérie orientale. Il est la conséquence de l'orogenèse mésozoïque qui a affecté le vieux socle plissé : la ceinture plissée d'Asie Centrale. Cet orogène a été plus actif dans la partie orientale de cette ceinture, avec effondrement et soulèvement de blocs crustaux. Le plus tardif est associé à la formation des bassins avec intrusion plutoniques et volcanisme. Les roches associées à ces événements structuraux sont essentiellement des molasses sédimentaires et volcanogènes, accompagnées d'intrusion de granites. La partie orientale de la ceinture plissée mésozoïque d'Asie Centrale est divisée en trois provinces (Khangaï-Yablonovy, ouest-Baïkal, et Mongol-Okhotsk) qui se distinguent par la nature pétrogrpahique des roches et leur style structural. La province Khangaï-Yablonovy est constituée d'un cortège pétrographique varié dont les formations sont limitées par des discordances.

L'origine et l'évolution structurale de cette ceinture montagneuse résultent de la collision de blocs issus des plaques sino-coréenne et sibérienne.

Les causes de la surrection de la chaîne montagneuse d'Asie Centrale ne sont pas élucidées mais les données géologiques et géophysiques permettent de proposer un modèle de migration de plaques contrôlée par un diapirisme mantellique.

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Mots-clefs : Ceinture orogénique, Mésozoïque, Ceinture Plissée Sibérienne.

ABSTRACT

The 1 000 km wide and 5 000 km long Central Asian mountain belt, which includes many of the Cenozoic rift basins of East Siberia, was produced by Mesozoic orogeny acting on an older folded basement – the Central Asian Fold Belt. The orogeny was most active in the eastern segment of the belt with the subsidence and uplift of crustal blocks, the latter being associated with the initiation of fault-related basins, plutonic intrusions and volcanism. The orogeny-related rocks within the belt are essentially sedimentary and volcanogenic molasse in association with granitoid intrusions. The Mesozoic eastern Central Asian Fold Belt is divided into three provinces (Khangai-Yablonovy, West Baikal and Mongol-Okhotsk) which differ in their geology and structural pattern. The Khangai-Yablonovy province displays the widest range of orogeny-related formations in five unconformity-limited groups.

The origin and evolution of the belt were controlled by the collision of large blocks of the old China-Korean and Siberian plates. While the mechanism involved in the creation of the Central Asian Fold Belt is still disputed, the available geological and geophysical data can be best explained by a plate-motion model with mantle diapirism.

Key words : Orogenic belts, Mesozoic, Siberian Fold Belt.

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INTRODUCTION

The Central Asian mountain belt, one of the largest structural units of Eurasia, was formed by orogenesis during the Mesozoic which acted on a system of Paleozoic and older fold terranes of different ages (MELNIKOV *et al.*, 1994). It is framed by the Siberian platform and West Siberian plate to the north, and by the North China and Tarim plates to the south (Fig. 1, 2 and 3) (BOGOLEPOV, 1972; BOGOLEPOV & ERMIKOV, 1973, 1979). At present, the belt is about 1 000 km wide and extends for almost 5 000 km from the Tien-Shan mountains to the Okhotsk sea (Fig. 1). During the Mesozoic it covered an even larger area as is shown by the widespread occurrence of sedimentary and volcano-sedimentary molasse at the base of the platform cover on the large West Siberian, and other minor young platforms around the belt (Fig. 3) (BASHARINA *et al.*, 1974).

The possible mechanisms for the formation of the Central Asian mountain belt are still open to discussion. BOGOLEPOV (1967), based on geophysical data indicative of an upwarp of the asthenosphere and high heat-flow beneath active areas of the fold belt, believed that mantle diapirism was the driving force. Others (KOMAROV *et al.*, 1984, 1989) argue that the belt was produced by granite doming. They suggest that the endogenic energy released by orogeny is expended on granite-gneiss doming and subsequent widespread emplacement of granites. This process is associated with a considerable increase in the volume of crustal material which forms megadomes *i.e.* systems of mountain ranges which are separated by intermontane basins.

Many workers also mention the presence of many thrusts and oblique-slip faults in the suture zones between the mountain range systems, which testifies to a transpression regime. KHAIN (1990) interprets the origin of the belt in terms of plate tectonics as being due to the collision of large lithospheric plates resulting in crustal shortening and the subsequent crustal heating and lithospheric density decrease.

The present structure of the Central Asian Belt may have been produced by relative motions of the constituent microplates within the framework of the major collision between the Indian, Eurasian and Arabic plates. The pattern of seismic activity which follows the major fault pattern supports the hypothesis that Central Asia consists of a number of microplates (ZONENSHAIN *et al.*, 1990). According to KHAIN (1990), Eurasia also collided, in the Mesozoic, with other plates and microplates to the south of it. On the western flank of the belt, the collision zone passed through North Badakhshan and South Kun-Lun during the Late Triassic to Early Jurassic, and through Central Badakhshan, the Parmirs and Central Tibetan plateau (Fig. 1), during the Late Jurassic to Early Cretaceous. The eastern flank was dominated by the collision of large fragments of the China plate with the Siberian plate, which resulted in the closure of the Mongol-Okhotsk ocean. The ensuing orogeny was not confined to the collision zone but it spread over a wide area reaching the margin of the Siberian craton (KHAIN, 1990).

Motion of the Pacific plate must have played a certain role in the evolution of East Asia (ZONENSHAIN & KUZMIN, 1992). From the Late Triassic to Early Cretaceous, subsidence of the eastern margin of the continent (now forming the Sikhote-Alin range, (Fig. 1)) was concurrent with an uneven uplift of the adjacent Central Asian Belt which initiated fault-related intermontane basins, plutonic intrusives and volcanism. During the Late Cretaceous and Paleogene, when the belt was being peneplaned, with the formation of a weathering crust and local slow sedimentation, the orogeny continued to the east (BOGOLEPOV *et al.*, 1972; KASHIK & MAZILOV, forthcoming).

The southward wedge-like projection of the Siberian platform into the fold belt must have played an important role in its evolution, as did the Punjab projection of the Indian plate which was called an injector by MOLNAR & TAPPONIER (1975). The two regions show a similar pattern of major faults (KHAIN, 1990) but the pre-rift structure of Siberia has a much longer history which began in Late Precambrian times and was completed in the Mesozoic (ALEXANDROV, 1990; DOBRETSOV & BULGATOV, 1991; MELNIKOV *et al.*, 1994).

1. — CENTRAL ASIAN FOLD BELT IN THE MESOZOIC. ASSYMETRY AND LIMITS

The Central Asian Fold Belt changed its limits throughout the Mesozoic. The constituent blocks of the belt developed quite independently though simultaneously and reflect its major evolutionary stages. During the Late Triassic to Early Jurassic, a major uplift of blocks occurred in the western and central segments of the belt; in the Early to Middle Jurassic orogenesis spread throughout the belt and, in the Late Jurassic to Late Cretaceous, continued in the eastern segment while, in the west, movements gradually abated giving way to broad subsidence of the belt margins and related sedimentation (KASHIK & MAZILOV, forthcoming).

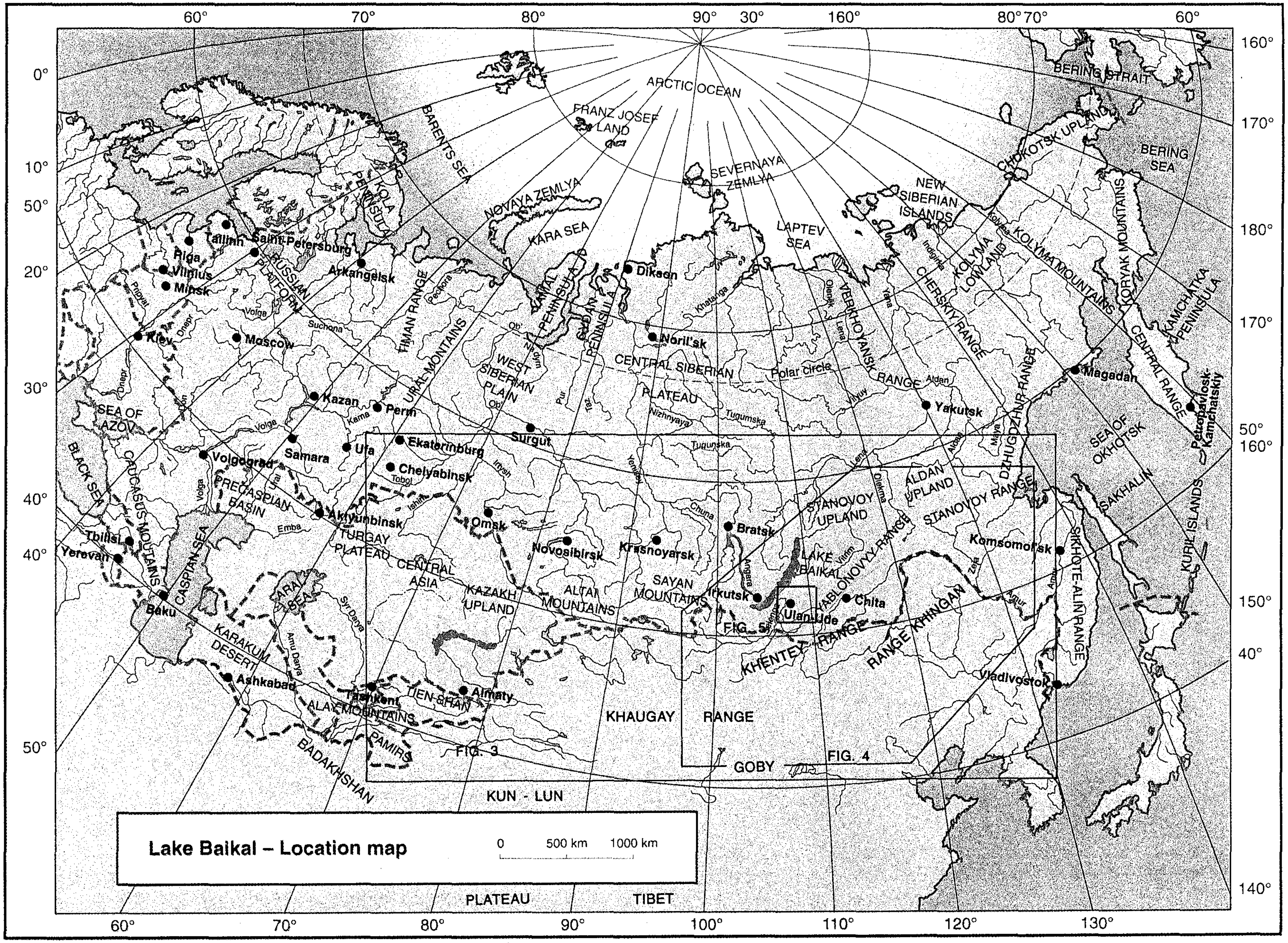

FIGURE 1
Location map of the study.

FIGURE 2

Location map of Lake Baikal.

The orogeny within the belt was essentially completed by the Late Cretaceous – Paleogene. The resultant Mesozoic features make an arcuate belt following the pattern of older folding. The orogeny-related rocks of the eastern and western zones differ considerably both in facies and age (Fig. 4 and 5); those to the east are essentially magmatic and range in age from Triassic to Late Cretaceous – Paleogene while those in the west are virtually amagmatic (with the exception of the Triassic volcanics found in the territory of the West Siberian plate) and range in age from Late Triassic to Early – Middle Jurassic. The eastern and western zones of the Eastern Central Asian Fold Belt meet in a north-south line running approximately from the southern tip of the Siberian platform to the north and to a northward swing of folds in the isthmus between the Tarim and North China plates to the south (BOGOLEPOV & ERMIKOV, 1979) (Fig. 3). This assymetry seems to be related to the southward projection of the Siberian platform. To the west the crust is 10 km thicker. Also the south western termination of the 1 800 km long north-east trending Eastern Siberia rift system abuts this line. The rift system was initiated in the Cenozoic (possibly in the Upper Mesozoic, LOGATCHEV, 1993) and is still developing (LOGATCHEV & ZORIN, 1992).

2. — GEOLOGICAL HISTORY OF THE EASTERN CENTRAL ASIAN FOLD BELT IN THE MESOZOIC

The eastern zone of the Central Asian Fold Belt has been studied for many years and there is considerable literature on the Mesozoic stratigraphy, tectonics, magmatism, etc.

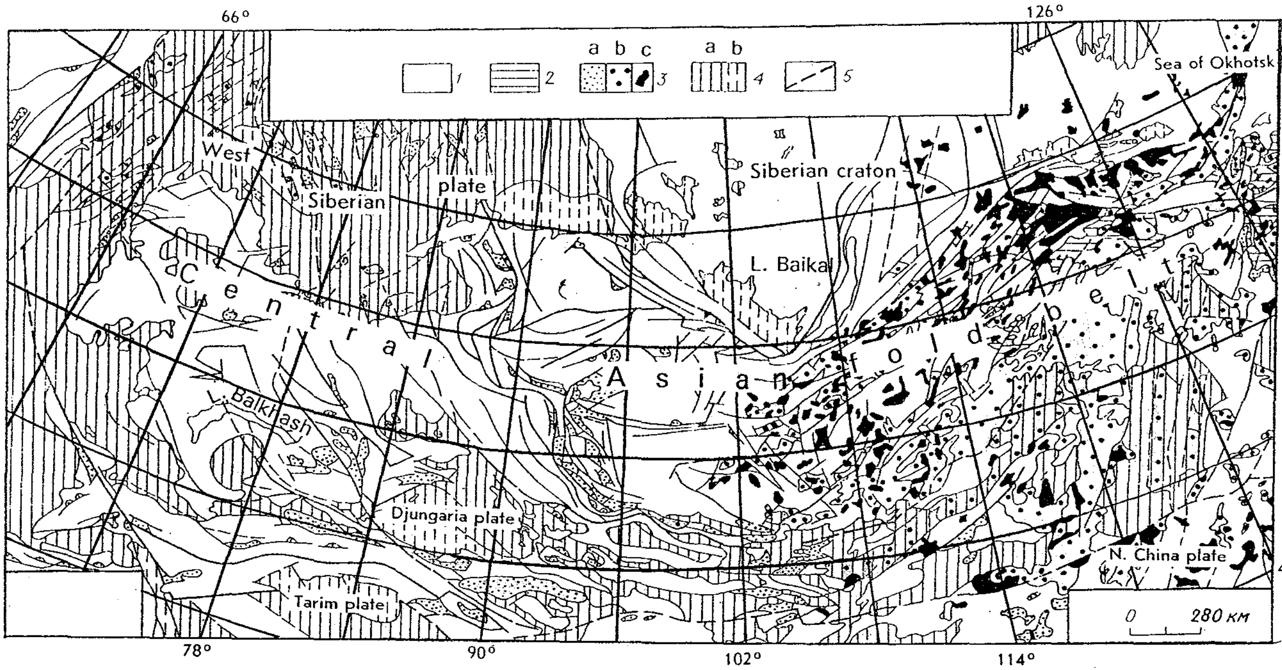

FIGURE 3

Mesozoic geological framework of the Central Asian Fold Belt between the Siberian craton, the Tarim and North China plates (after BASHARINA *et al.*, 1974).

1 : pre-Mesozoic basement; Mesozoic elements; 2 : marine sedimentary formations in Mongol-Okhotsk province; 3 : orogenic formations : a) sedimentary, b) volcano-sedimentary, c) intrusives; 4 : platform formations : a) sedimentary cover, b) foredeeps; 5 : Faults.

(FLORENSOV, 1960; 1964; BYKHOVER, 1961; YANSHIN, 1974; etc). The authors often disagree on the Mesozoic geological processes which acted in the region, but their major contribution has been the enormous volume of data which they have collected. The present overview is based on a division of the Mesozoic Eastern Central Asian Fold Belt into three provinces which differ in their geology and structural pattern (Fig. 4). Associated formations 1 (including volcanics and related intrusives) with similar relations to geomorphic features (ERMIKOV, 1972) which are limited between stratigraphic gaps or angular unconformities, are assigned to tectonostratigraphic group 2.

The lowest Mesozoic groups in the area are dated at Upper Triassic and rest with angular stratigraphic or structural unconformity on older deformed Paleozoic and Precambrian terranes and complexes. The unconformity is regional, and is easily followed throughout most of the Central Asian Fold Belt but becomes less pronounced on the periphery. In the eastern zone, Mesozoic continental sedimentation started after a Mid-Triassic gap which was followed, in North Mongolia, west and central Trans-Baikal and the Stanovik areas, by volcanism with associated granitoid intrusions. Along the Siberian platform margin, in the West Baikal area and Aldan upland (Fig. 1), wide foredeeps developed in which coal-bearing molasse accumulated during the Early to Middle Jurassic (FLORENSOV, 1960; SOLOVIEV, 1968).

Further east, in eastern Mongolia and the western part of the Amur river drainage area, a narrow oceanic basin which was carried over from the Paleozoic, existed until the Middle Jurassic. It, in turn, suffered orogenesis in the Upper Jurassic and Cretaceous contemporaneously with the neighbouring Khangai-Yablonovy area (Fig. 4) (BYKHOVER, 1961; NAGIBINA, 1963; FOGELMAN, 1968).

2.1. MESOZOIC KHANGAI-YABLONOVY PROVINCE

The Khangai-Yablonovy Province borders Lake Baikal to the south and east and has an area of 1 000 000 km^2. It covers the Mongolian Khangai and Khentei mountain ranges (MELNIKOV *et al.*, 1994), west and central Trans-Baikal, the Yablonovy range, most of the Vitimskoye plateau and the Stanovoy range (Fig. 1 and 4). The province is delineated by old deep fault zones.

The orogeny-related formations occur in five groups (see above § 3) which range in age from Triassic to Early Paleogene, and rest with angular unconformity on generally NE-SW trending folded Proterozoic to Late Paleozoic terranes. They comprise sedimentary and volcanogenic molasse and volcanics-associated hypabyssal intrusives. Terrigenous facies are restricted to well-defined basins which occupy topographic lows. The volcanics outcrop on ridges bordering the basins and the intrusives on the horsts separating the basins. (Fig. 6, 7 and 8).

2.1.1. Triassic – Lower Jurassic group 4

The Triassic to Lower Jurassic group is composed of volcanics exposed on drainage divides and mountain slopes in association with, in the west, alkali granites and syenites or, in the east, with normal amphibole and biotite granodiorites and granites. The volcanics, comprising rhyolite, dacite, microsyenite, syenite porphyry, ignimbrites and agglomerate, are up to 100 m thick. Sediments are absent.

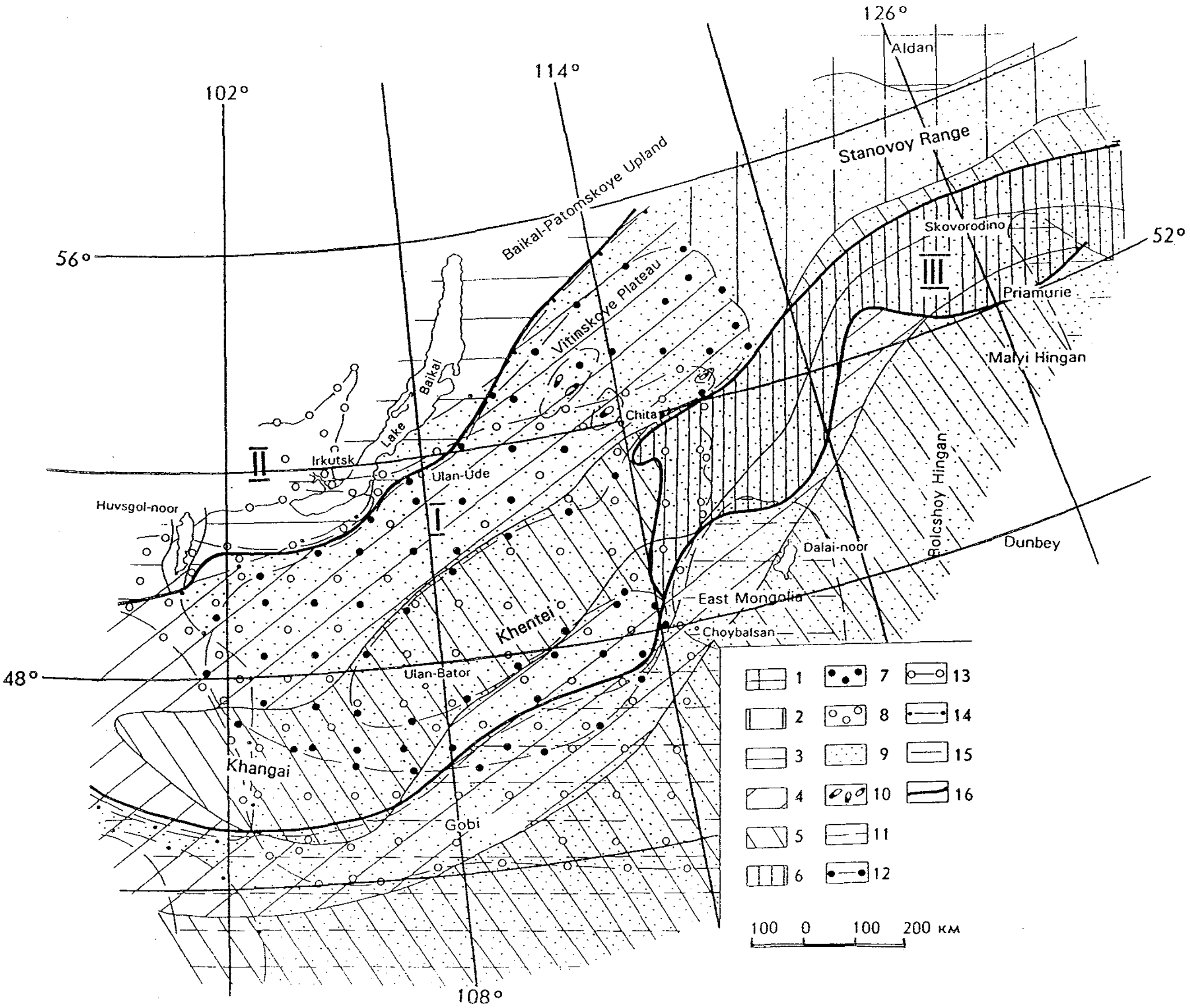

FIGURE 4

Generalized map of Mesozoic structures of the eastern zone of the Central Asian Fold Belt.
Pre-Mesozoic folded basement : 1 : Archean; 2 : Early Proterozoic; 3 : Late Proterozoic; 4 : Early Paleozoic; 5 : Late Paleozoic. Extension of Mesozoic groups; 6 : Marine-facies sediments. Mesozoic orogenic groups; 7 : Triassic-L. Jurassic; 8 : L-M. Jurassic; 9 : U.Jurassic-L.Cretaceous; 10 : U. Cretaceous – Paleogene; 11 : Late Cretaceous – Paleogene sediment cover. Generalized limits of the extension of Mesozoic orogenic groups; 12 : Triassic – L. Jurassic; 13 : L.-M. Jurassic; 14 : U. Jurassic – L. Cretaceous; 15 : U. Cretaceous – Paleogene; 16 : Limits of the Mesozoic provinces of Central fold belt. I : Khangai-Yablonovy. II : West Baikal. III : Mongol-Okhotsk.

The granitoids either have intrusive contacts with the volcanics or show gradational transition to them in terms of grainsize but both volcanics and intrusives have the same chemistry and mineralogy. Their ages vary from 175 to 210 My (SOLOVIEV, 1968; RUBLEV *et al.*, 1985; ALEXANDROV *et al.*, 1988).

2.1.2. Lower – Middle Jurassic group

The Lower – Middle Jurassic group comprises three formations. A 1 000 m thick conglomerate formation composed of boulder and pebbly beds with thin intercalations of sandstones or tuffs and volcanics of variable composition occurs in central Trans-Baikal. In west Trans-Baikal the formation underlies and grades into a formation constituted by 1 500 m of trachyandesite lavas alternating with trachybasalt lavas with minor pyroclastics and sediments. The lavas extend into North Mongolia (DEVIATKIN *et al.*, 1990; KOMAROV, 1972). The volcanics are succeeded by limnic facies of detritics about 500 m thick comprising conglomerates, sandstones, siltstones and shale with coal seams which occur widely in North Mongolia and west Trans-Baikal. Where this formation is not transitional from lavas it is floored by conglomerate. This group occurs in fault-related basins (grabens and halfgrabens), and shallow depressions, such as the Tugnuy basin (Fig. 7), in west and central Trans-Baikal. They display

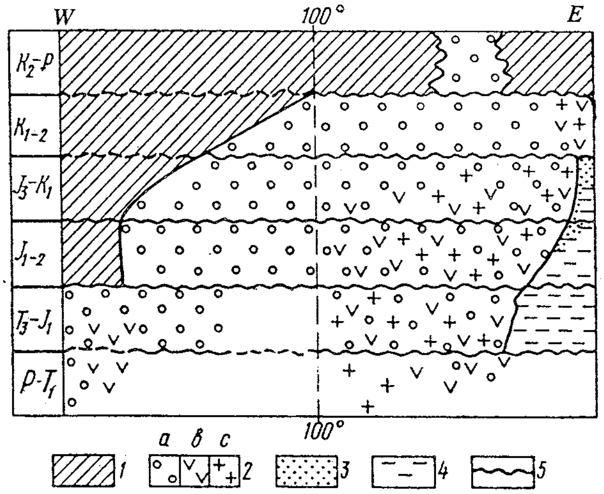

FIGURE 5

West to east diagram of Mesozoic major groups related to regional unconformities with facies variations in the Central Asian Fold Belt (after BOGOLEPOV & ERMIKOV, 1979).

1 : Platform sedimentary cover; 2 : Orogenic formations : a) Sedimentary, b) Volcanogenic, c) Intrusives; 3 : Continental shelf marine facies; 4 : Marine flysch facies with spilitic lavas; 5 : Regional unconformity (observed and inferred).

shallow dips up to 20° with steeper dips occurring close to fault zones. The age is constrained by an assemblage of Early to Mid-Jurassic insects found just below the lavas and numerous fresh water pelecypods and plants in the coal seams (SKOBLO & LIAMINA, 1962; FLORENSOV, 1964).

2.1.3. Upper Jurassic – Lower Cretaceous group

Upper Jurassic – Lower Cretaceous rocks occur in grabens throughout the Khangai-Yablonovy province (Fig. 4). They display a similar sequence to that in the Lower – Mid Jurassic group with a local conglomerate, sandstone unit up to 300 m thick infilling small grabens east of Lake Khubsugul and forming the lowest unit in some other basins in North Mongolia (NAGIBINA *et al.*, 1977; DEVIATKIN *et al.*, 1990). This is followed by a more widespread 1 000 m thick volcanic formation which comprises mainly porphyritic trachybasalt and trachyandesite with associated tuffs and agglomerates. In central Trans-Baikal the volcanic unit lies directly on folded Paleozoic and is more acidic with, besides trachy- and porphyritic andesite and basalt, trachy- and porphyritc rhyolites occurring along with a lot of pyroclastics (FOGELMAN, 1968). The volcanics are succeeded by a conglomerate, sandstone and shale unit with interbeds of brown coal. The grabens, which are either half-graben or symmetrical, can be oval or linear with an inherited NE-SW

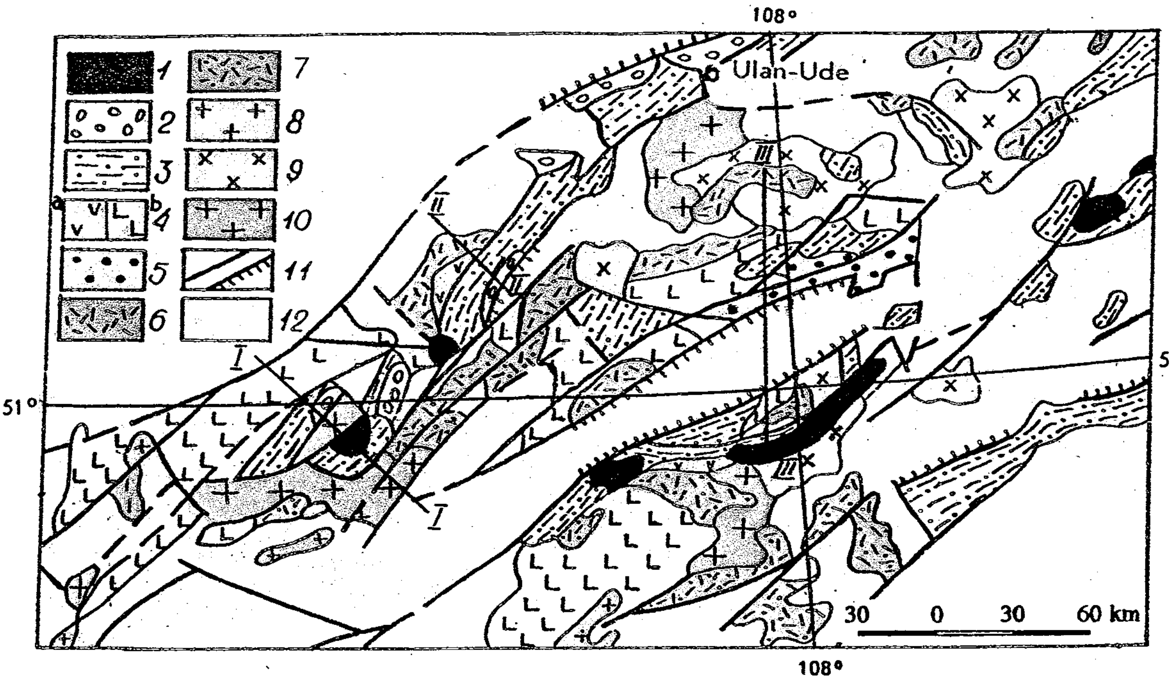

FIGURE 6

Mesozoic formations of the central South Baikal area intramontane basin infill :

1 : Early-Late Cretaceous alkali basalts; 2 : Early-Late Cretaceous conglomerate; 3 : Middle Jurassic – Early Cretaceous coal-bearing detritic series (incl. conglomerate, sandstone and shale); 4 : Jurassic trachyandesite and trachybasalt : a) Late Jurassic, b) Early-Middle Jurassic; 5 : Early – Middle Jurassic conglomerate. Intramontane basin slope and floor; 6 : Late Triassic – Early Jurassic alkali rhyolite; 7 : Triassic basalt, andesite and rhyolite; 8 : Late Jurassic sub-alkali granitoids; 9 : Late Triassic – Early Jurassic alkali granitoids; 10 : Triassic gabbro, diorite and granite; 11 : Faults : normal, strike-slip and thrusts; 12 : Pre-Mesozoic rocks.
I-I, II-II, III-III : Lines of cross sections Fig. 7.

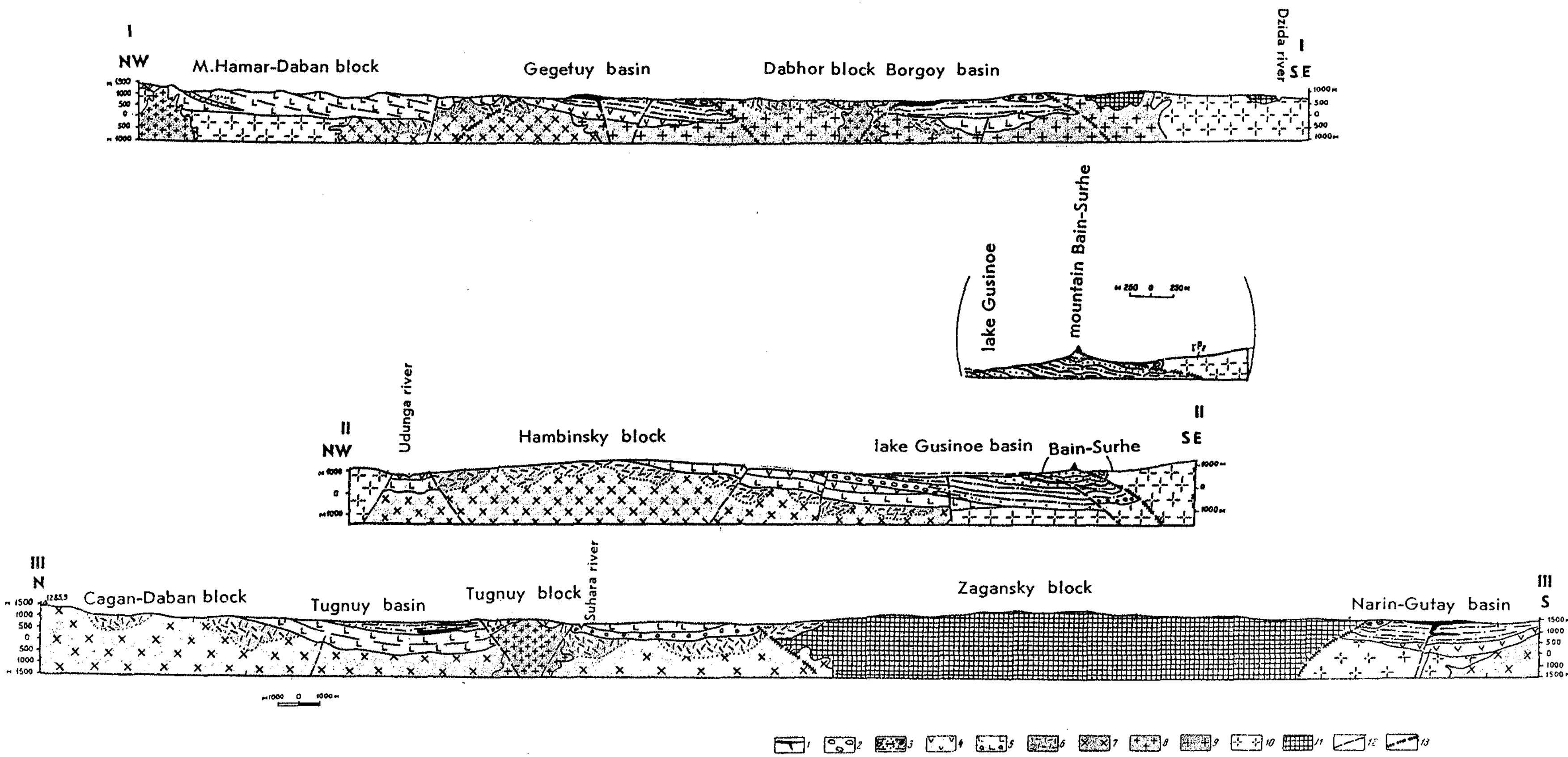

FIGURE 7
Geological cross sections across major tectonic blocks in the western Trans-Baikal area (after SOLOVIEV, 1968).
See Fig. 6 for the positions of I-I, II-II, III-III.

1 : Early – Late Cretaceous alkali basalt sill and sheets; 2 : Early – Late Cretaceous conglomerate; 3 : Early Cretaceous sandstones and siltstones with coal seams (Middle Jurassic in the Tugnuyi basin) ;4 : Late Jurassic trachyandesites, trachybasalts and their tuffs; 5 : Early – Middle Jurassic trachyandesites, trachybasalts; 6 : Late Triassic – Early Jurassic alkali rhyolites; 7 : Late Triassic – Early Jurassic alkali granites and syenites; 8 : Late Jurassic (?) granites and syenites; 9 : Triassic gabbro, diorites and granites; 10 : Paleozoic diorites and granites; 11 : Pre-Mesozoic (Proterozoic ?) basement; 12 : Normal and reverse faults; 13 : Thrust and strike-slip faults.

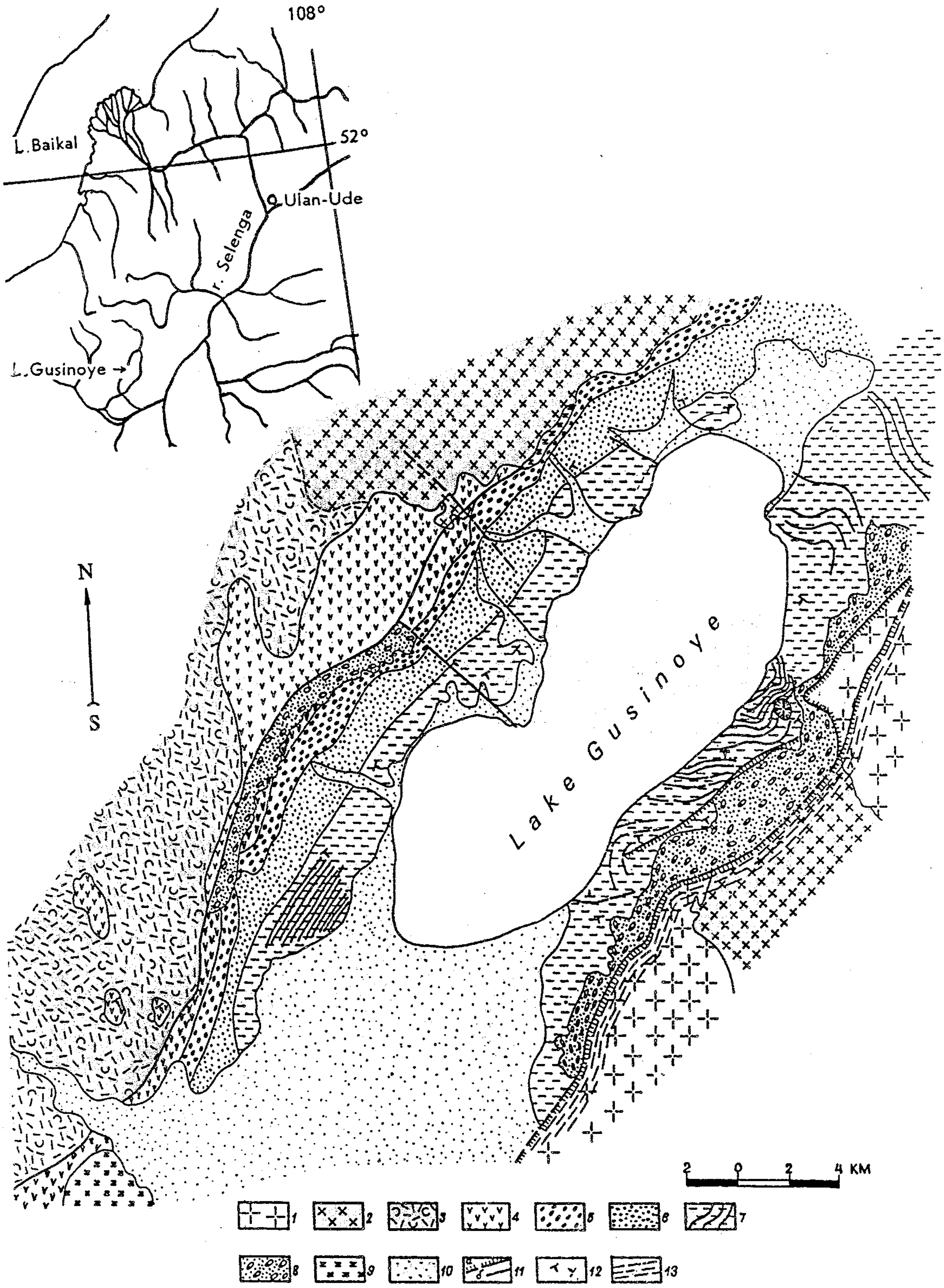

FIGURE 8

Generalised geology of the Lake Gusinoye basin as an example of a typical Mesozoic intermontane basin in the Central Asian Fold Belt (after ERMIKOV, 1972).

1 : Paleozoic granitoids; Mesozoic formations : 2 : Late Triassic – Early Jurassic alkali granitoids; 3 : Late Triassic – Early Jurassic alkali rhyolite; 4 : Early – Late Jurassic trachyandesite and trachybasalt; 5-7 : Early Cretaceous sediments : 5. conglomerate, 6. sandstone, 7. sandstone, siltstone and shales with coal interbeds; 8 : Early – Late Cretaceous conglomerate/breccia; 9 : Early – Late Cretaceous trachybasalt; 10 : Quaternary sediments; 11 : Faults : a) Thrust, b) Normal and reverse; 12 : Dip; 13 : Fracture zone (associated with major thrust).

trend (e.g. the Lake Gusinoye, Borgoy, Narin-Gutay and other basins, Fig. 7 and 8). They occur in "en échelon" zones along major deep faults. Dips in the grabens are 10-15° but steeper near faults. Abundant fish, molluscs, dinosaur bones, plants, spores and pollen found in the coals not only give good age control but also show that climatically, in the Early Cretaceous, the Khangai-Yablonovy province was at the boundary between the moderate Canadian and the subtropical Europe-Sinian zone (MARTINSON, 1961; BYKHOVER, 1961; FLORENSOV, 1964; KOTOVA, 1964, 1968; BUGDAEVA, 1989).

2.1.4. Lower – Upper Cretaceous group

The Lower – Upper Cretaceous group occurs as either detritics or trachybasalt lavas. The detritics are conglomerates and breccias (cemented by coarse-grained sandstone) which become finer laterally to form sandstones and clay. They range in thickness from 250 m to 1 000 m from west to central Trans-Baikal. Mega-breccias occur where the grabens are limited by thrust faults (Fig. 7 and 8) and, according to SOLOVIEV (1968), are debris flows from advancing thrust sheets. A suite of intrusives (trachy-dolerite, crinanite, teschenite 9 and shoshonite 10) is mostly derived from alkali and calc-alkali olivine basalt magma (BELOV, 1963). These cut Lower Cretaceous coal-bearing sediments in western and central Trans-Baikal, and possibly in other areas of the Khangai-Yablonovy province, and are inferred to be of Lower to Upper Cretaceous age.

2.1.5. Upper Cretaceous – Paleogene group

The Upper Cretaceous – Paleogene group comprises a thin greenish grey to dark grey clay formation with lignite beds in some basins of the central Trans-Baikal area and also a weathering residue on the Vitimskoye plateau (Fig. 4). The latter, which rest unconformably on Upper Jurassic – Lower Cretaceous coal-bearing series, can be varicoloured and locally limonitic or sandy clay, rubble, sands, pebbles or boulders. These formations are undeformed and are similar to the platform cover formations south of the province.

2.1.6. Intrusives

Intrusives are abundant in the province (KOMAROV, 1972). They outcrop in the ranges between basins and show a genetic proximity to the various volcanics. There are three groups : Early, Middle and Late Mesozoic. The Early Mesozoic intrusives belong to a dioritic granite and alkali granitoid association and form massifs up to 600 km^2 in area. Middle Mesozoic dyke swarms of fine-grained syenite, porphyritic syenite, trachydolerite, essexite and granite porphyry, are exposed on the interbasin domal uplifts. They extend for 30 to 40 km and are so abundant that some workers describe them as continental spreading zones (STUPAK, 1990 a, b). Infra-volcanic intrusions of trachydolerite, essexite 11, bostonite 12, granite porphyry and microgranite, are found locally intruded into Middle Mesozoic volcanics. Late Mesozoic intrusives occur throughout the province but are most common in the eastern area. They comprise diorite granites and subalkaline granitoids and they show a proximal relationship to the andesitic and rhyolitic volcanics. Basaltic sheets (of trachydolerite, glenmuirite 13, teschenite, monzonite, syenite) and dykes (of gabbro diabase 14, monzonite, diorite, syenite and both syenitic and felsitic porphyry), cut Lower Cretaceous sediments and are overlain by Quaternary ones (see § 2.1.4.). Their radiometric age ranges from 100 to 127 My (SOLOVIEV, 1968; LITVINOVSKIY *et al.*, 1989).

2.2. WEST BAIKAL PROVINCE FOREDEEP FORMATIONS

The West Baikal province is located on the western margin of the Siberian platform. During the Mesozoic (especially during the Early to Middle Jurassic) it experienced broad subsidence and deposition of continental molasse at the same time as the Central Asian Fold Belt to the south was in its orogenic phase of uplift and initiation of faulted basins with concommittant detritic infill and volcanism.

The continental molasse comprises two laterally equivalent facies : conglomerate to the south-east and a coal-bearing series to the north. The coal-bearing sandstone, siltstone and claystone series is 500 m thick in the upper Angara river and has a basal sand and conglomerate member. Both units coarsen to the south-east and coalesce into the Baikal conglomerate formation south of Angara. The age of the coal-bearing facies is reliably determined as Early-Middle Jurassic from abundant plant fossils, spore and pollen, molluscs, fish and insects (FLORENSOV, 1960; SOLOVIEV, 1968). On the south-east side of Lake Baikal, several occurrences of conglomerates are correlative with the Baikal conglomerates based on lithology and structural environment. Both are overthrust by Precambrian rocks by either the Angara thrust or, in the case of the south-east Baikal conglomerates, by a southeast extension of the same thrust.

2.3. MONGOL-OKHOTSK PROVINCE

The Mongol-Okhotsk province (Fig. 1, 3 and 4) extends eastwards along the Amur river and its sources in Trans-Baikal and Mongolia and projects into the fold belt as a narrow (less than 200 km wide) strip. Throughout most of the Mesozoic, it was a remnant ocean which only closed and was affected by the orogeny at the end of Late Jurassic and in the Cretaceous.

2.3.1. Upper Triassic – Jurassic open marine and continental shelf formations

Strongly folded marine sediments fill a system of east-west trending basins often bordered with younger faults. The upper age limit of these sediments varies throughout the province from Mid-Jurassic in the west, to Late Jurassic in the east of the area. The earliest are Late Triassic marine conglomerates, sandstones and argillites (now slate) with a total thickness of more than 5 500 m and up to 1 000 m of spilites and diabases. Jurassic rocks are of open marine facies and comprise argillite and flysch with interbedded sandstone and argillite, and also a continental-shelf facies of conglomerate, sandstone and argillite. The Jurassic marine sediments, which locally rest with angular unconformity on folded Paleozoic, comprise up to 3 000 m of argillite and also include a detritic formation (up to 100 m thick) of interbedded siltstone, sandstone and pebbly conglomerate, in the middle. The argillites are succeeded by up to 2 500 m of flysch – regular alternating siltstone, argillite and polymict sands. To the south-east both the argillite and flysch formations change facies into shelf and continental terrigenous facies which are up to 3 500 m thick. The conglomerate intercalated in the marine argillites also occurs in the shelf facies and is thus a useful horizon marker. The marine sediments were apparently folded in the Late Jurassic as all the above lying sediments show a different style of deformation (the latter are brachyformic compared with the former linear ones).

2.3.2. Upper Jurassic – Lower Cretaceous infill of intermontane basins and Lower – Upper Cretaceous group

Late Jurassic to Cretaceous volcanogenic-sedimentary molasse infills fault-related intra-montane basins, as in the Khangai-Yablonovy province (Fig. 4). Keeping to the chronological order of the marine sequence from west to east (see § 2.3.1.) : the lowest molasse varies from Late Jurassic in the west (*i.e.* in the east Trans-Baikal area) to Early Cretaceous in the upper Amur area to Late Cretaceous in the extreme east of the Mongol-Okhotsk province.

The Upper Jurassic – Lower Cretaceous group comprises a volcanic and a limnic-facies coal-bearing sedimentary formation. The volcanics, up to 1 800 m thick, are trachyandesite, andesitic porphyrite and dacite, trachybasalt and tuff with interbeds of tuffaceous sandstone and conglomerate. These are conformably overlain by more than 1 000 m of Early Cretaceous limnic-facies detrics : conglomerate, sandstone, siltstone and clay, calcareous, bituminous and siliceous shales interbedded with brown coal. In some basins acid volcanics intercalate in the lower part of the Lower Cretaceous sediments. In others, volcanic intercalations are of basic composition.

The Lower – Upper Cretaceous group is represented by a conglomerate formation in east Trans-Baikal and by a volcanogenic-terrigenous formation in the east of the province. Up to 1 000 m of unsorted blocky conglomerate occur at the edge of thrust-defined basins. The volcanics in the Amur area comprise (less than 1 000 m of) andesitic porphyries, andesitic basalts, quartz and felsitic porphyries and quartz albitophyres 15, with tuffs and tuffaceous conglomerate at the base, and interbeds of conglomerate and, more rarely, sandstones and siltstones. All the rocks of this group are strongly deformed by faulting and fault-related folding.

2.3.3. Intrusives

Intrusives outcrop on the interbasin blocks. In east Trans-Baikal they are diorite, granodiorite, biotite granite and granosyenite and their porphyritic varieties vary in age from Middle Jurassic to Early Cretaceous. In the Amur area intrusives are less abundant.They are Early Cretaceous subalkali granodiorite, syenite and granite. No age data are available.

3. — CONCLUSION

The above overview of the Mesozoic and its structure, precursor to the Eastern Siberian Cenozoic rifting (Logatchev, 1993), shows that the eastern flank of the Central Asian Fold Belt, framed between the Siberian and Chinese cratons, was the site of active orogenic movement throughout the Mesozoic (Ermikov, 1972; Dobretsov & Bulgatov, 1991). This phase was longest in the Khangai-Yablonovy province (Fig. 4), with movements (with intermittant associated volcanism) lasting from the Triassic through to the Early Paleogene. The resulting structures significantly modified the pre-Mesozoic framework of the region. While an oceanic basin existed during the Triassic and Jurassic in easternmost Asia and sedimentation and foredeeping acted on the Siberian craton in the Central Asian Belt, the uneven movement of crustal blocks in a framework of overall uplift and magmatic activity, especially in the eastern zone, was considerable with extensive basaltic volcanism and subvolcanic intrusions. During the Late Cretaceous and the Paleogene, movements in the Central Asian Belt abated (while orogeny continued further east) and isostatic peneplanation of the area began (Bogolepov *et al.*, 1972). The sequence of major events in the Central Asian Fold Belt during the Mesozoic established from geological and structural data does not contradict the interpretation of many workers (*e.g.* Khain, 1990; Zonenshain & Kuzmin, 1992) who claim that the Mesozoic deformation was driven by lithospheric motion of old continents and microcontinents to the south of the Central Asian Belt. Unlike the East Siberian rift zone which has been in an extensional regime throughout the Cenozoic, the Central Asian Fold Belt evolved in the Mesozoic under compression. The compressive regime favoured the reactivation of old fault zones which resulted in an "en échelon" series of horsts, grabens and half grabens which in turn were affected by younger (mostly Late Cretaceous) thrust faulting (Ermikov, 1972).

Such a model, together with that of mantle diapirism proposed by Ladynin (1990) and Fotiadi *et al.* (1990), may provide a satisfactory fit to the available geological and geophysical data on the structure and dynamics of the lithosphere in Eastern and Far Eastern Siberia.

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