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New Results of the Moma Rift System and Coeval Structures in Yakutia, Russian Federation

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THEME 3: Plate Boundary Problems in the Laptev Sea Area

Summary: Preliminary results obtained during CASE-3 expedition (1998) to the Alpine history of the central part of Yakutia (Russian Federation) are discussed. The Moma rift system is the southeastern part of an Arctic graben assemblage , which often comprises half grabens, and can be traced southeastwards from the Laptev Sea into the central Siberia. The grabens of the Moma rift system are mostly filled with Tertiary clastic rocks with lignite seams of very low coal rank; basalts of unknown age occur locally at the base. The graben fill does not show compressive structures of tectonic origin. Extension prevails what is corroborated by local Holocene bimodal volcanism (alkaline basalt and rhyolite) along the Moma graben boundary. In contrast, the SW margin of the Zyryanka basin, a foreland basin in front of the adjacent mountains Ilin'-Tas, was affected by Alpine compression. The compression continued to Pliocene time. Analysis of pebble composition and sedimentary structures indicate that sediments supplied to the foreland basin were derived from the west or southwest and that the Alpine compressive deformation began around the Cretaceous/Tertiary boundary.

INTRODUCTION

The Federal Institute for Geosciences and Natural Resources (BGR) in Hannover (Germany) and the Institute of Geological Sciences of the Siberian Branch of the Russian Academy of Science in Yakutsk (Republic Sakha, Yakutia, Russian Federation) organized a field expedition (CASE-3: Circum-Arctic Structural Events) in 1998 to some key areas in the Moma rift system.

The Moma rift system was first described by REZANOV (1964) as a system of troughs and associated uplifted blocks of high neotectonic activity. This view was later revised by GRACHEV et al. (1967, 1973, 1982), who showed that the structure of the Moma rift was more complicated than previously thought. FUJITA et al. (1990) described these structures and referred to them as the Moma rift system, the name used in the present paper. NAJMARK (1976) concentrated on the neotectonic activity in the Moma region, which includes the central Moma-Selennyakh rift trough flanked by uplifted blocks. The Moma rift system belongs to a major graben assemblage which runs southeast from the Gakkel Ridge in the Arctic Ocean through the Laptev Sea and inland for a distance of more than 1000 km to the Moma rift system and possibly further. The Moma rift system is situated south of the Cenozoic Yana-Indigirka basin (Fig.1). The rift system is not always well defined geographically and with respect to the geologic history, and important problems remain unsolved mostly owing to lack of data. Conflicting interpretations of the tectonic characterisation of the Zyryanka basin are common in the literature. Some of the conflicting issues are discussed here. Due to their different natures, the Zyryanka basin and the Moma rift system will be treated as autonomous structures in present account.

Only preliminary results can be given here, mostly based on field observations and on the literature. Our observations focussed on tectonic features and to a minor degree on sedimentary structures in the Moma rift system (Uyandina basin) and in the Zyryanka basin particularly with a view to finding evidence of Alpine compression. A more detailed description of the results including laboratory data (geochronology, geochemistry, palaeomagnetism, petrography and coalification) together with an interpretation of unpublished records is in preparation.

GEOLOGICAL SETTING

The Moma rift system comprises numerous grabens shown on the map (Fig. 1) as separate grabens linearly arranged and trending in southeastern direction or as a parallel to partly fan-shaped array of structures exposed over a width up to 400 km. The longest unit is the Moma graben, which follows the Moma valley, and its prolongation to the northwest. IMAEV et al. (1998) incorporate the Zyryanka basin with the Moma rift system. Other authors consider this basin to be the foreland basin of the mountains Ilin'-Tas (FUJITA et al. 1990). The grabens are not always bounded by faults on both sides; these are then asymmetric grabens and in some localities the Tertiary strata is said to occur in troughs, which are not bounded by border faults in the sketch maps.

The infill of the grabens rests unconformably on the Verkhoyansk-Kolyma Mesozoides (belt folded during the Mesozoic)

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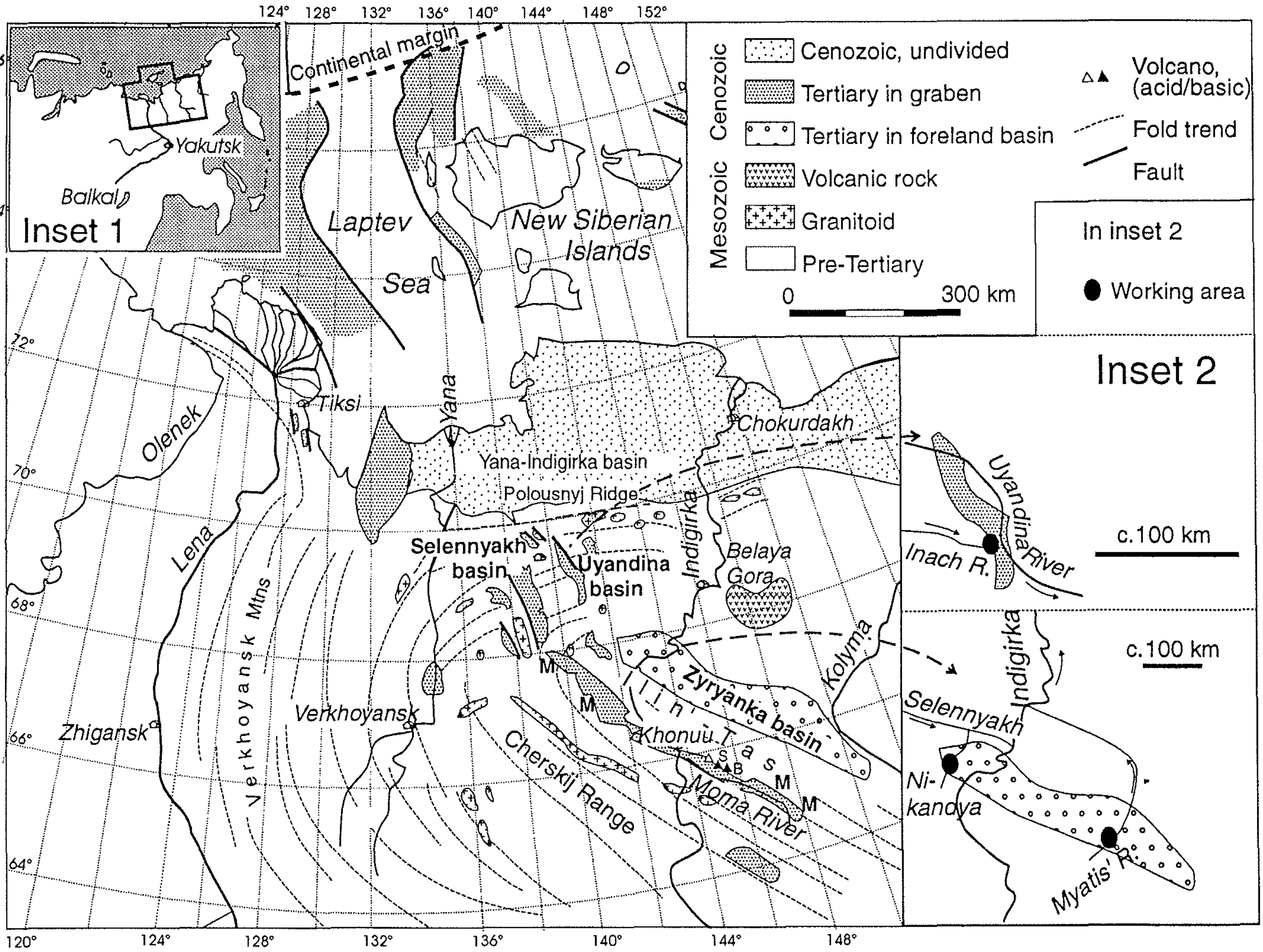

Fig.1: Regional position of the Moma rift system which is south of the Yana-Indigirka Cenozoic basin (M = Moma graben, S = Serdtse-Kamen' volcano, B = Balagan-Tas volcano).

(Parfenov 1991, Prokopiev 1998, Oxman 1998), which were last deformed in the Late Cretaceous. Generally, the graben fill ranges in age from Palaeogene to Neogene, contains very low-maturity lignite deposits (Grinenko et al.1998 a,b, Baranova et al. 1979), and is locally overlain unconformably by Pleistocene sediments. However, Grachev (1982) and Najmark (1976) inferred a younger graben fill and concluded that the early rifting stage commenced in Pliocene time.

Volcanic rocks related to the rifting are rare. Partly, they are represented by basalts of hitherto unknown age and composition. They are located at the base of the graben fill. There is a Quaternary basalt volcanoe (Balagan-Tas) 0.3-0.35 Ma in age (Layer et al. 1993) in the Moma graben where it coincides with the Moma valley (Vas'kovskij 1949, Argunov & Gavrilov 1960) and elsewhere two rhyolitic domes are reported (Fujita et al. 1990). The above-mentioned young volcanic rocks and hot springs on the northeastern side of the Moma graben seem to be aligned along the northeastern border fault. However, detailed studies of Argunov & Gavrilov (1960) have shown that the Balagan-Tas volcano is associated with a NE–SW fault and not to the NW–SE-trending border fault.

Another example of conflicting interpretations involves the earthquakes in this region. They are inferred by some authors to be associated with the Moma graben (Rezanov 1964, Patyk-Kara & Grishin 1972), whereas others (Imaev & Grinenko 1989) infer the Moma rift system to be almost aseismic. Fujita et al. (1990) show that the accuracy of teleseismic location of epicentres is not better than ±20 km and therefore consider the problem of links between earthquakes and individual faults as still largely unsolved. It is more likely that the earthquakes belong to a broad seismic belt (Cherskij seismic belt according Parfenov et al. 1988, Imaev et al. 1995) located between a gravity high, the Kolyma-Omolon microcontinent in the east (Parfenov 1991) and the external zone of the Verkhoyansk Mountains in the west, which is characterized by low gravity. This seismic belt covers the entire Moma rift system and includes the adjacent mountainous areas of the Cherskij Range and Ilin'-Tas. Thus, it covers the region of high neotectonic activity of Rezanov (1964). It is dominated by a sinistral transpressional regime (Koz'min 1986, Parfenov et al. 1988, Imaev et al. 1998). In contrast, the region of Gakkel Ridge and the Laptev Sea is characterized by an extensional regime reflected by the kinematics of recent earthquakes (Avetisov

1991, KOZ'MIN 1986). Heat flow data for this region are scarce and tends to lead to conflicting interpretations; thus it cannot be used to show that the grabens are associated with elevated heat flow.

The tectonic deformation of the Tertiary sequences of Yakutia varies in nature. Often compressive structures are reported even in graben successions (GRINENKO & IMAEV 1989, IMAEV & GRINENKO 1989, IMAEV et al. 1995). However, extensional deformation is more widespread in the graben fill.

The Tertiary sediments in the Zyryanka basin have been the object of particular interest (GAJDUK et al. 1990, 1993). They are intensely folded on the northeast of the Ilin'-Tas (Andrei-Tas plus Moma Range), which is composed of Jurassic flysch and Cretaceous shallow marine sediments on the northeastern side.

FIELD OBSERVATIONS OF CASE-3 EXPEDITION

The preliminary field results of the CASE-3 expedition are as follows.

Uyandina graben

The Uyandina graben was studied along the Inach River, a tributary of the Uyandina River (Fig.1). It belongs to the northwestern part of the Moma rift system. The Uyandina graben contains more than 300 m of Upper Oligocene to Pliocene sediments (age constraints mostly from sporomorphs; GRINENKO et al. 1998 a, b) (Fig.2), which can be subdivided into the fine-grained, carbonaceous, lacustrine Elikchan Group (Upper Oligocene to Middle Miocene) containing lignite deposits and the overlying fluvial conglomerate/sand sequence of the Uyandina Group (Upper Miocene to Pliocene). The boundary between the two groups is a disconformity (GRINENKO et al. 1998 a,b). The youngest member of the graben fill is the Pleistocene fluvial Inach Conglomerate (less than 10 m thick), which rests disconformably on the Uyandina Group. Judging from the composition of the pebbles, which are mostly carbonates, the detritus was derived from the carbonate rocks of the Palaeozoic basement, known from the adjacent western graben shoulder. The eastward transport direction is indicated by cross-bedding and pebble imbrication studies. Locally, more than 30 m of flat lying basalts of unknown age occur, most likely representing the base of the graben succession, which contains at least three hiatuses associated with disconformities. The graben cuts the Palaeozoic limestone structures, which were formed during the Mesozoic orogeny, at a high angle. At one locality along the Inach River compressive structures have been reported in the Tertiary sequence by IMAEV & GRINENKO (1989). However, during CASE-3 no compressional structures could be identified unambiguously at this locality. Mostly the sediments are flat-lying. Faults are exclusively normal faults. They are partly covered by younger conglomerates which is evidence for their synsedimentary origin. Locally, small folds a few cm to dm across occur near normal faults. These rare, local and very weak compressional features were caused by the synsedimentary normal faulting in graben structures creating local compression and convolute distortion of previously water-saturated strata. The degree of coalification is very low. It attains only the lower lignite grade.

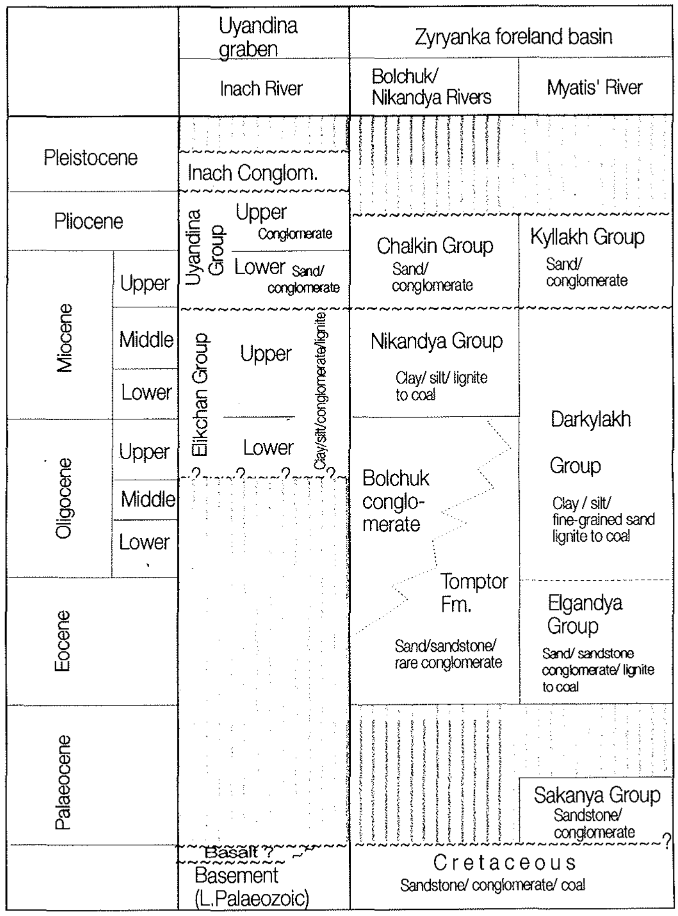

Fig.2: Stratigraphic overview of the Tertiary sequences in regions visited during the CASE-3 expedition.

Moma graben

A reconnaissance flight along the Moma River revealed only gently inclined Cretaceous and Tertiary/Quaternary sediments in the Moma graben. This dip may be the result of tilting due to faulting. Due to lack of time, it was not possible to carry out a field check in the Moma graben.

Zyryanka basin

In the Zyryanka basin, which is a foreland basin northeast of the Ilin'-Tas (Fig.1), the Tertiary sediments (Eocene to Pliocene) overlie the Mesozoic succession apparently concordantly despite a Palaeocene hiatus. The southwestern side of the Zyryanka basin only was studied in two sections: along the Bolchuk and Nikandya Rivers and along the Myatis' River.

The tectonic history of the Zyryanka basin and the adjacent Ilin'-Tas in the section along the Nikandya and Bolchuk Rivers is characterized by a lithological transition between the Jurassic and Cretaceous sequences. The Jurassic sediments are intensely folded (locally with cleavage) in the Ilin'-Tas attaining elevations of more than 2000 m above sea level. The Cretaceous sediments can be assigned to the Zyryanka basin. They are less folded than the Jurassic sequences. Jurassic flysch sedimentation in a deep water basin was gradually substituted by a shallow-water environment in Cretaceous times and followed by continental conditions evidenced by Cretaceous coal measures. It is highly unlikely that tectonic compression took place around the Jurassic/Cretaceous boundary. However, later thrusting may have occurred along this boundary.

Thus, the Ilin'-Tas and adjacent Zyryanka basin formed a depocentre where the depositional environment in the deepest part changed from deep-water flysch conditions in the Jurassic to shallow-water and/or continental conditions in the Cretaceous. At the same time, the axis of the basin shifted towards the foreland, which was situated in northeast. After a tectonic event around the Cretaceous/Tertiary boundary (see below) Tertiary sedimentation continued in the Zyryanka basin.

The Tertiary sequences attain a total thickness of more than 2000 m. They start with a fluvial sequence of sand to conglomerate comprising the Tomptor Formation/ Bolchuk Conglomerate and Elgandya Group of Eocene to Oligocene age (mostly based on sporomorph associations), which contain lignite and coal. These fluvial formations are followed by more than 1000 m of lacustrine, lignite- to coal-bearing, predominantly silty sediments of the Darkylakh Group of Oligocene to Middle Miocene age. Tertiary sedimentation ended with the Kyllakh Group which made up mostly of conglomerates. Its sedimentation began in Late Miocene and continued into the Pliocene.

In contrast to the Jurassic/Cretaceous conformable boundary, the contact between Cretaceous and Tertiary sediments may be a thrust, an unconformity or a sedimentary hiatus. On the base of observations on the pebble composition in Tertiary conglomerates, we infer that a tectonic event took place at the Cretaceous/Tertiary boundary. The pebbles are composed of volcanic rocks and Upper Triassic sediments (containing the bivalve *Monotis* c.f. *ochotica*, Upper Norian guide fossil, written comm. from A.M.Trushelev, Yakutsk), as well as Jurassic (shales showing cleavage and graywackes) and Cretaceous rocks (granite including contact-metamorphic rocks). During the CASE-3 expedition, the general transport direction of sedimentary debris was deduced from cross-bedding and imbrication analysis as towards the north and northeast. This agrees with Fatkhullin (1982), who observed that at that time sedimentary debris was transported both to the east and north into the Zyryanka basin. These observations contrast with the interpretation by Gajduk et al. (1990, 1993) based on the predominance of volcanic pebbles in Tertiary conglomerates, which are not known in the Moma region as source area. Gaiduk et al. (1990) reported that in the central part of the SW flank of the Zyryanka basin (Myatis' River section) sediment transport was to the south during the Eocene and to the north in Late Miocene–Early Pliocene time. However, the observations made during CASE-3 show that part of the Ilin'-Tas and/or adjacent areas to the west was the source area during the Tertiary sedimentation and most likely underwent compressive deformation prior to the Tertiary sedimentation, i.e., at the Late Cretaceous/Palaeogene boundary. Subsequently, the Tertiary strata were folded in Pliocene to Quaternary times. From this supposition it was concluded that a compressional event occurred in the Zyryanka basin in the Late Miocene–Early Pliocene.

As we have just seen, the Tertiary fill underwent compressive deformation to varying degrees at the end of Tertiary or beginning of Quaternary periods jointly with the underlying Cretaceous sequences (Gajduk et al. 1990). The Tertiary and Cretaceous rocks in the Nikandya River area are only weakly folded, whereas in the Myatis' River section the entire sequence comprising Lower Cretaceous and Tertiary sequences are strongly deformed. Cretaceous rocks showing folds of 100 m wavelength and are thrust over Tertiary and Pleistocene sediments which are now steeply inclined (75° to the N to almost vertical) in a strip over 10 km wide. Furthermore, along the Myatis' River section, the Cretaceous sequence is thrust onto the Elgandya Group; the uppermost Cretaceous is tectonically cut out. The intensity of deformation of the Tertiary sediments increases with proximity to the Ilin'-Tas. The coalification of Cretaceous and Tertiary rocks is higher (coal rank) than in the Moma rift system proper (lignite rank). In comparison with the older event the deformation migrated more towards the foreland where the deformation decreases.

CONCLUSIONS

1) The Tertiary fill of the grabens of the Moma rift system, which rests unconformably on folded basement, only underwent extension during the Alpine event. Small compressive structures are of secondary origin. The coalification ranging in lignite rank is weak.

2) Evidently, the grabens of the Moma rift system differ in tectonic character from the Zyryanka basin.

3) The tectonic nature of the Zyryanka basin is still in discussion. However, it is most likely to be a foreland basin and have developed gradually from a deep-water Jurassic flysch basin into a Cretaceous shallow-water basin. Thus, it differs in its palaeotectonic history and its higher degree of coalification (coal rank) conspicuously from the grabens of the Moma rift system proper, where the fill rests unconformably on sequences folded in Mesozoic times (Mesozoides).

4) Studies of transport direction and pebble provenance including primary deformation features in the coarse-grained Tertiary sediments of the Zyryanka basin provide evidence that the source area was located in the west where Mesozoic basement was deformed during another folding event around the Cretaceous/Tertiary boundary apart from the main folding of the Zyryanka basin margin during late Tertiary to early Quaternary times.

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