
Application of magnetic susceptibility for correlation of the Lower Triassic red beds of the Baltic basin

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Correlation of red beds by magnetic susceptibility is a new and cheap research method in Lithuania. Lower Triassic samples were collected from three boreholes of Lithuania and one well of Kaliningrad Region (Russia). Magnetic susceptibility of 687 samples was measured with a KLY-2 kapabridge. Having magnetic susceptibility data from the borehole Vladimirovo-1 (stratotype of lower Triassic sediments in the Baltic region) we can compare them to magnetic susceptibility data from the boreholes Galzdonai-1, Žvelsėnai-8 and Kernai-1. The result of the study is a new stratigraphical correlation of lower Triassic in the Baltic basin. Earlier it was supposed that all Triassic sediments in the boreholes Kernai-1 and Žvelsėnai-8 correspond to the Nemunas Formation, but the new data indicate presence of both the Nemunas and Palanga Formations.

Key words: Lithuania, Lower Triassic, magnetic susceptibility

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INTRODUCTION

The Triassic variegated rock mass, as in the adjacent regions of its distribution (in Poland, Germany), reflects specific conditions of its formation, i.e. a wide submerging continent with periodically repeating sedimentation and accumulation of deposits and breaks in sedimentation, with activity of lakes and rivers in former desert plains of arid climate, where representatives of organic world, which are important for correlation of deposits, almost did not develop or were absent. Because of such a complex nature, the paleontologic, lithologic and geochemical studies of the accumulated deposits are not fully reliable for the stratigraphic subdivision.

So it was very important to find the methods that could relate the previous stratigraphic subdivision with the global schemes or schemes of large regions which are significant for the correlation. The methods should also help to compile unified stratigraphic legends, local detailed legends applicable for mapping (including the legends for the Baltic region).

To obtain more effective results for the subdivision of variegated Triassic rocks, it is necessary to apply the most complete complex of old and new methods. At present, the paleomagnetic stratigraphy has gained great significance in rock stratification. However, it is a very expensive method. In this study we used a new and cheap research method – a correlation of the Lower Triassic red beds according to their magnetic susceptibility.

STRATIGRAPHY AND CORRELATION

Stratigraphy of the Triassic deposits in this region is based mainly on lithological data, because the paleontological data (gastropods, ostracods, phyllopods and plant remains) are rather scarce and insufficiently studied (Киснерюс, Сайдаковский, 1972; Сувейзdis, 1986).

In Lithuania, the Triassic deposits are subdivided into the Purmaliai and Nadruva Groups, and correspond to the Induan and the Olenekian, respectively. In turn, the Purmaliai group is subdivided into the Nemunas,

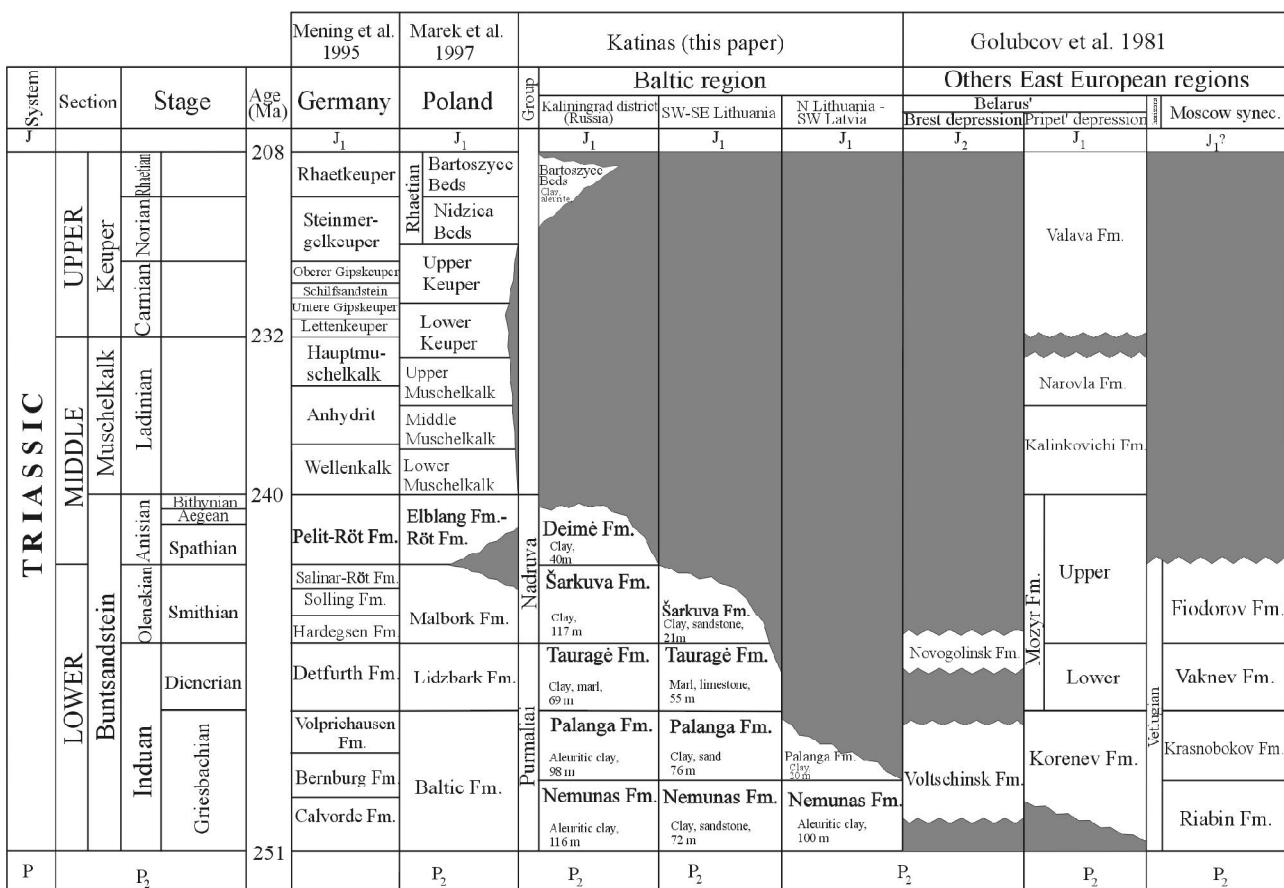


Fig. 1. Correlation of Triassic rocks in the Baltic basin (stratigraphical scheme)

1 pav. Triaso uolienu koreliacijos Baltijos baseine

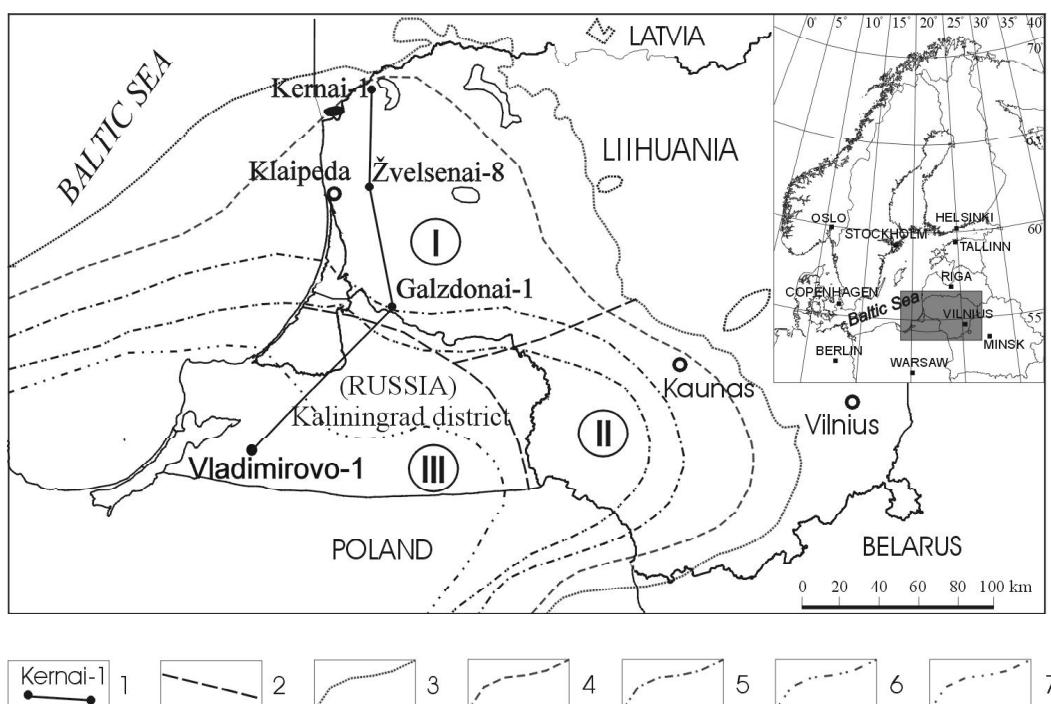


Fig. 2. Distribution of Lower Triassic formations in Lithuania and Kaliningrad Region (Russia): 1 – boreholes; 2 – facies: I – N-Lithuanian, SW-Latvian, II – SW-SE-Lithuanian and III – Kaliningrad Region; 3 – Nemunas Fm., 4 – Palanga Fm., 5 – Tauragė Fm., 6 – Šarkuva Fm., 7 – Deimė Fm.

2 pav. Apatinio triaso uolienų paplitimas Lietuvoje ir Kaliningrado srityje (Rusija): 1 – gręžiniai, 2 – facijos: I – Š-Lietuva ir PV-Latvija, II – PV-PR Lietuva ir III – Kaliningrado sritis, 3 – Nemuno sv., 4 – Palangos sv., 5 – Tauragės sv., 6 – Šarkuvos sv., 7 – Deimės sv.

Palanga and Tauragė Formations, and the Nadruva Group include the Šarkuva and Deimė Formations (Fig. 1) (Suveizdis, 1994).

In the study region of Lower Triassic sediments, the following three structural-facies zones are defined: I – the northern zone including Western Lithuania and the southwestern part of Latvia; II – the southeastern zone comprising the southwestern and southeastern parts of Lithuania; and III – a zone including Kaliningrad Region (Fig. 2) (Григялис, Киснерюс, 1982; Paškevičius, 1994).

The **Nemunas Formation** consists of dolomitic clays and marls, reddish-brown in colour with bluish-grey irregular spots, and interbeds of greenish and bluish-grey sandstones and marls, and locally brown dolomites in the lower part of the section. White and light-grey sands, sandstones, gritstones, limestones, reddish-brown clays, silts and marls compose the eastern and southeastern margins of the Nemunas Formation. The stratotype of the Nemunas Formation is in the Vladimirovo-1 borehole at a depth of 878–993 m (Fig. 3).

The **Palanga Formation** is composed of highly calcareous dolomitic clays, marls and silts, reddish-brown in colour with greenish and bluish-light grey round and irregular spots, with interbeds of bluish-grey and light grey sandstones, siltstones, marls and oolitic limestones, occasionally with veinlets and small inclusions of gypsum and selenite. In the same sections, sulfates were found in the Nemunas Formation. The lithological boundary between the Palanga Formation and the overlying Tauragė Formation rocks is distinct. The stratotype of the Palanga Formation is in Vladimirovo-1 borehole at a depth of 785–878 m.

The **Tauragė Formation** is represented by variegated calcareous deposits. According to its lithological composition, this formation is subdivided into the lower, middle and upper subformations. The lower subformation consists of violet, lilac and reddish-violet marls with interbeds of red-brown, bluish and greenish-grey calcareous clays, argillaceous sandstones and oolitic limestones. The middle subformation is composed of greenish-grey and grey marls with interbeds of oolitic limestones.

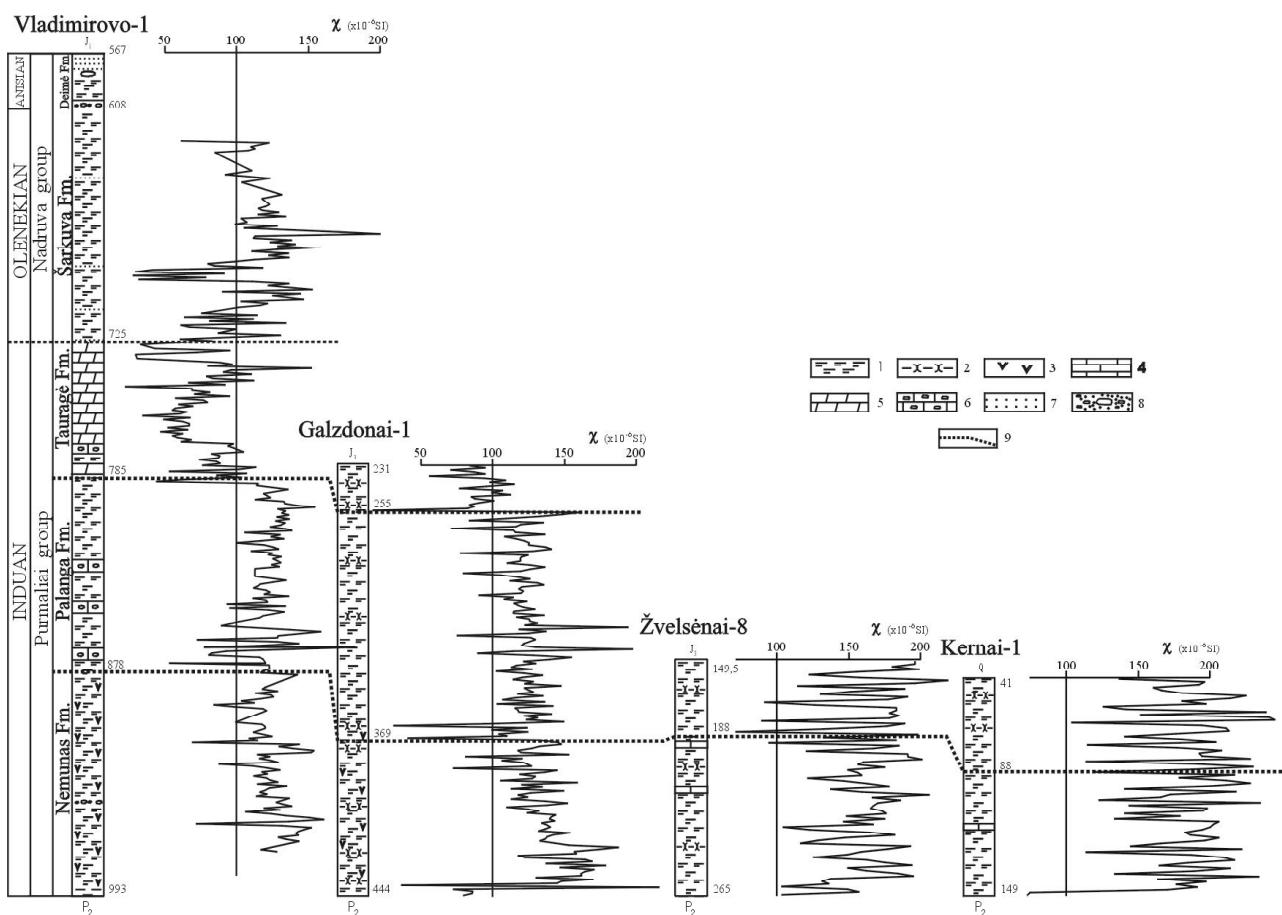


Fig. 3. Lower Triassic correlation profile, boreholes Vladimirovo-1, Galzdonai-1, Žvelsėnai-8 ir Kernai-1: 1 – silty clay, 2 – siltstone, 3 – anhydrite, 4 – limestone, 5 – marl, 6 – oolitic limestone, 7 – sand, sandstone, 8 – conglomerate, 9 – magnetic susceptibility

3 pav. Apatinio triaso koreliacinis profilis Vladimirovo-1, Galzdonų-1, Žvelsėnų-8 and Kernų-1 gręžiniuose: 1 – aleuritingas molis, 2 – aleurolitas, 3 – anhidritas, 4 – klintis, 5 – mergelis, 6 – oolitinė klintis, 7 – smėlis, smiltainis, 8 – konglomeratas, 9 – magnetinis imlumas

The upper subformation is represented by violet, violet-lilac marls, red-rown calcareous sandy silts and clays with bluish-grey spots and interbeds. The stratotype of the Tauragė Formation is in Vladimirovo-1 borehole at a depth of 725–785 m.

The Šarkva Formation consists of dolomitic clays, marls, silt sands, sandstones and conglomerates, red-brown in colour, with greenish-grey interbeds and irregular spots. In the middle part of the sequence carbonate concretions appear, forming a conglomerate-like texture of the rock. The major part of Šarkva Formation is composed of calcareous clays and marls. Brown silts occur as thin interbeds. In the western part of the Baltic region the Šarkva Formation is represented by grey sands, highly calcareous argillaceous conglomerates, and also by variegated marls and clay. The sequence starts with characteristic brown calcareous sands and silts, indicating the beginning of new sedimentary cycles, and ends with red-coloured calcareous clays. The stratotype of the Šarkva Formation is in the Vladimirovo-1 borehole at a depth of 608–725 m.

The Deimė Formation is represented by clays, sands, sandstones and conglomerates. The clays are noncalcareous or slightly calcareous, red-brown, brown, bluish-grey, grey in colour. They form beds in the lower part and interbeds in the upper part. Intercalations of white and light grey sands were found in the middle part of the formation, and the bluish-grey an pale-brown sandstones occur in the upper part. Conglomerates can be observed in the middle part of the Deimė Formation. In the west and east, the Deimė Formation is represented by more argillaceous deposits, red-brown and brown in colour (Киснерюс, Сайдаковский, 1972). The stratotype of the Deimė Formation is in Vladimirovo-1 borehole at a depth of 567–608 m.

EXPERIMENTAL AND ANALYTICAL METHODS

The correlation of the Lower Triassic red beds using magnetic susceptibility is a research method used in Lithuania. Investigation of variegated Triassic beds and their magnetic susceptibility was first applied in the United Kingdom. Red and green clay interbeds were investigated, which were similar to the lower Triassic sediments from the Baltic basin (Hountslow et al, 1995). The correlation of the Pleistocene sediments by magnetic susceptibility was also applied in Poland and West Ukraine (Nawrocki et al, 1996). Lake sediments were investigated in New Zealand (Turner, 1997). The magnetic susceptibility of sediments and volcanic rocks from oceanic boreholes was investigated in Japan (Fukuma, 1998). Devonian sediments were investigated in Czech Republic and Morocco (Crick et al., 2001).

Lower Triassic samples for magnetic susceptibility investigation were collected from three boreholes in Lithuania and one well in Kaliningrad Region (Russia). The borehole Vladimirovo-1 a is stratotype of the lower Triassic sediments of the Baltic region. 304 samples

from the borehole Vladimirovo-1, 217 from Galzdonai-1, 86 from Žvelsénai-8 and 80 from Kernai-1 were taken. The magnetic susceptibility was measured with a KLY-2 kapabridge (AGICO, Czech Republic) in the Paleomagnetic Laboratory of the Polish Geological Institute. All the data were recalculated for 10 g. In each borehole, a diagram of magnetic susceptibility versus depth was constructed.

RESULTS OF THE EXPERIMENTAL INVESTIGATIONS

The magnetic susceptibility in the borehole Vladimirovo-1 (993–878 m) ranges from $130\text{--}150 \times 10^{-6}$ SI in the lower part of the Nemunas Formation to 110×10^{-6} SI in the upper part of the formation (Fig. 3). At the boundary between the Nemunas and Palanga Formations the magnetic susceptibility decreases to 50×10^{-6} SI. The magnetic susceptibility of the Palanga Formation (878–785 m) increases to 150×10^{-6} SI in the upper part of the formation. In the layer of the Tauragė Formation (785–725 m), the magnetic susceptibility ranges from 50 to 100×10^{-6} SI. The magnetic susceptibility in the lower part of the Šarkva Formation (725–608 m) changes from 50×10^{-6} SI to $100\text{--}150 \times 10^{-6}$ SI in the middle part of the Formation, whereas in the upper part it is less than 50×10^{-6} SI.

Having the magnetic susceptibility data from the borehole Vladimirovo-1 (stratotype of the lower Triassic sediments in the Baltic region), we can compare these data to data from the boreholes Galzdonai-1, Žvelsénai-8 and Kernai-1.

According to magnetic susceptibility data from the borehole Galzdonai-1, the Nemunas Formation was revealed in the interval from 444 to 365 m. The magnetic susceptibility (similarly to the borehole Vladimirovo-1) decreases from 150×10^{-6} SI (and more) in the lower part of the formation to $100\text{--}150 \times 10^{-6}$ SI in its upper part (Fig. 3). The Palanga Formation was distinguished in the borehole Galzdonai-1 from 369 to 255 m. At the contact between the Nemunas and Palanga Formations the magnetic susceptibility decreases in the same way as in the borehole Vladimirovo-1. The Tauragė Formation in the borehole Galzdonai-1 was identified from 255 to 231 m. In the beds of the Tauragė Formation the magnetic susceptibility was about $50\text{--}100 \times 10^{-6}$ SI.

The Nemunas Formation in the borehole Žvelsénai-8 was detected from 265 to 188 m. The magnetic susceptibility (as in the borehole Vladimirovo-1) decreased from 150×10^{-6} SI to 100×10^{-6} SI (Fig. 3). At the boundary between the Nemunas and Palanga Formations the magnetic susceptibility suddenly drops and increases to 150×10^{-6} SI.

By comparing the magnetic susceptibility data from the boreholes Vladimirovo-1 and Kernai-1 we cannot distinguish the Nemunas Formation, possibly because the borehole is located at the margin of the Triassic basin.

The magnetic susceptibility data were compared with the previous paleomagnetic data (Fig. 4). According to

the magnetic susceptibility data, a change from the normal to reverse magnetic polarity in the boreholes Galzdonai-1 and Kernai-1 corresponds to the boundary between the Nemunas and Palanga Formations. The obtained results allowed to distinguish Triassic sediments in the borehole Kernai-1, i.e. the interval from 149 to 88 m corresponds to the Nemunas Formation, while the interval from 88 to 41 m corresponds to the Palanga Formation.

Earlier (Katinas, Nawrocki, 2003) it was supposed that all Triassic sediments in the boreholes Kernai-1 and Žvelsėnai-8 correspond to the Nemunas Formation, but the new data indicate the presence of the Nemunas and Palanga Formations in the boreholes Kernai-1 and Žvelsėnai-8.

DISCUSSION AND CONCLUSIONS

The boundary between the Nemunas and Palanga Formations corresponds to the base of the reversed magnetic polarity and the top of the normal magnetic polarity.

The normal magnetic polarity has the maximum thickness not only in the profile of lower Triassic sediments from Lithuania, but also in Triassic sediments on a global scale (Katinas, Nawrocki, 2003).

The boundary between the Palanga and Tauragė Formations is identified at the upper limit of the second normal magnetic polarity and the lower limit of the second reverse magnetic polarity.

The lower Triassic sediments in the boreholes Kernai-1 and Žvelsėnai-8 should be subdivided into the Nemunas and Palanga Formations (Fig. 4), but this subdivision is not quite good, because magnetostratigraphy, unlike lithology, cannot be the basis for distinguishing formations.

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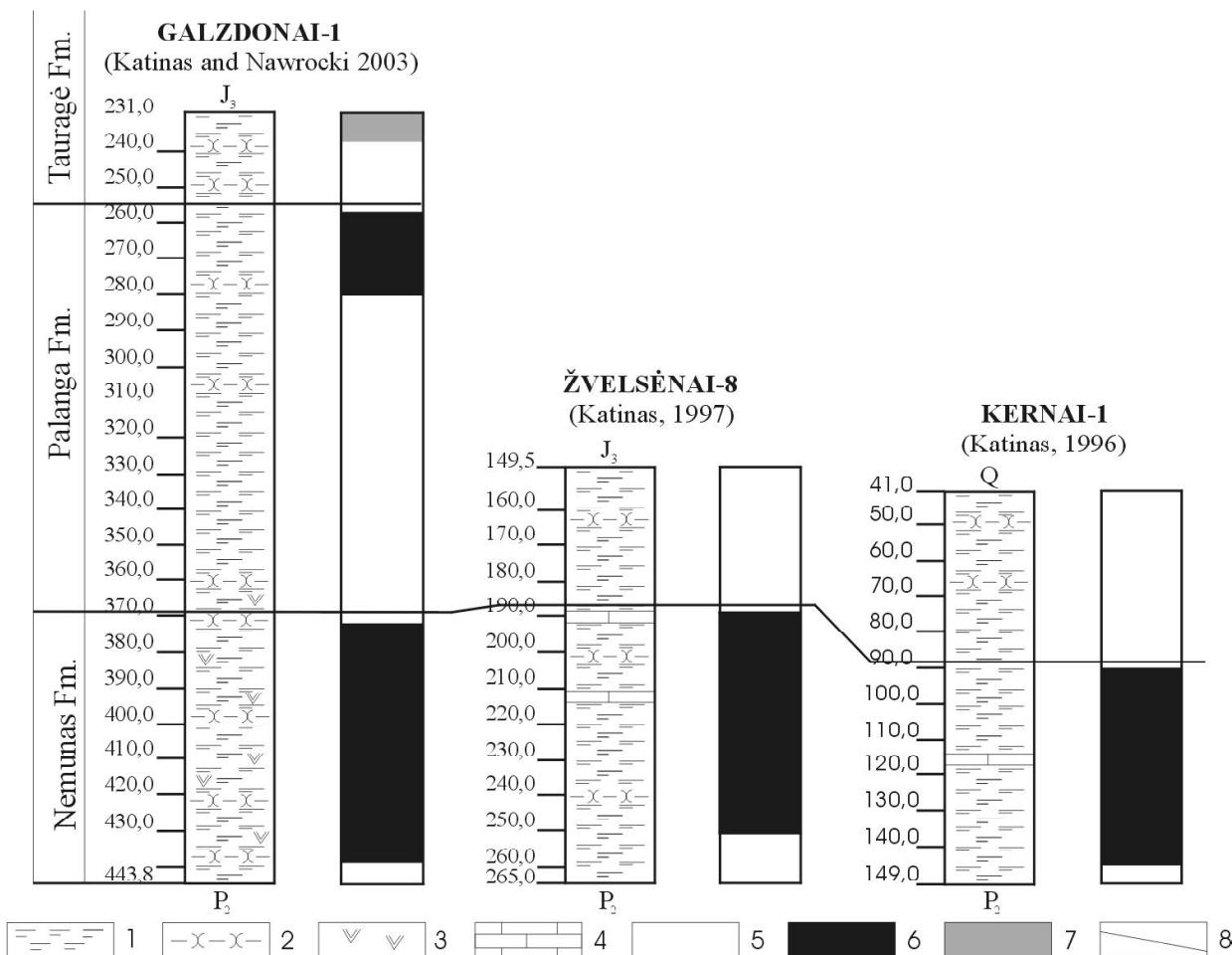


Fig. 4. Paleomagnetic profile of boreholes Galzdonai-1, Žvelsėnai-8 and Kernai-1 (after Katinas, Nawrocki, 2003):
1 – silty clay, 2 – siltstone, 3 – anhydrite, 4 – limestone, 5 – reverse magnetic polarity, 6 – normal magnetic polarity, 7 – uncertain magnetic polarity, 8 – correlation

4 pav. Galzdonų-1, Žvelsėnų-8 ir Kernų-1 grėžinių paleomagnetinis profilis (Katinas & Nawrocki, 2003): 1 – aleuritinas molis, 2 – aleurolitas, 3 – anhidritas, 4 – klintis, 5 – atvirkštinis magnetinis poliškumas, 6 – normalus magnetinis poliškumas, 7 – neaiškus magnetinis poliškumas, 8 – koreliacija

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APATINIO TRIASO RAUDONSPALVIU UOLIENU KORELIACIJA VAKARŲ LIETUVOS PANAUDOJANT MAGNETINIO IMLUMO DUOMENIS

Santrauka

Apatinio triaso stratigrafija Vakarų Lietuvoje iki šiol nėra tiksliai ir vienodai traktuojama. Nors šia tema atlikta ir paskelbta ne mažai darbu, tačiau nėra bendros nuomonės dėl margaspalvio triaso nuogulų stratigrafinio skirstymo. Norėdami gauti tikslesnius rezultatus, pabandėme pritaikyti naują, Lietuvoje iki šiol nenaudotą, magnetinio imlumo metodą. Iš Vievio kerno saugyklos buvo paimti triaso uolienu pavyzdžiai iš Vladimirovo-1, Galzdonų-1, Žvelsėnų-8 ir Kernų-1 grėžinių. Pavyzdžių ėmimo intervalas – vienas metras. Iš Vladimirovo-1 grėžinio buvo pa imti 304 pavyzdžiai, iš Galzdonų-1 – 217, iš Žvelsėnų-8 – 86, iš Kernų-1 – 80 pavyzdžių ir išmatuotas jų magnetinis imumas. Atlikus laboratorinius tyrimus buvo sudarytas Vladimirovo-1, Galzdonų-1, Žvelsėnų-8 ir Kernų-1 grėžinių apatinio triaso uolienu magnetinio imlumo koreliaciniis profilius. Rezultatai buvo lyginti su paleomagnetiniu profiliu Galzdonų-1, Žvelsėnų-8 ir Kernų-1 grėžiniuose. Gauti duomenys rodo, kad:

- Nemuno ir Palangos svitų riba reikia laikyti normalaus magnetinio poliškumo zonos padą ir atvirkštinio magnetinio poliškumo zonos kraigą. Reikia pastebeti, kad normalaus magnetinio poliškumo zona Nemuno svitoje yra pati didžiausia triaso pjūvyje, tiek Lietuvoje, tiek ir kitur.

- Palangos ir Tauragės svitų riba reikia laikyti antrosios normalaus magnetinio poliškumo zonos pabaigą ir atvirkštinio magnetinio poliškumo zonos pradžią.

- Kernų-1 ir Žvelsėnų-8 grėžinių triaso uolienu pjūvyje turi būti išskirtos Nemuno ir Palangos svitos.

- Palangos svitos paplitimo ribą Pabaltijo triaso uolienu svitų paplitimo žemėlapyje reikia vesti gerokai šiauriau, nei iki šiol buvo rodoma žemėlapiuose.

Валентас Катинас, Ежи Навроцкий

КОРРЕЛЯЦИЯ НИЖНЕТРИАСОВЫХ КРАСНОЦВЕТНЫХ СЛОЕВ В ЗАПАДНО-БАЛТИЙСКОМ РЕГИОНЕ С ПОМОЩЬЮ МАГНИТНОЙ ВОСПРИИМЧИВОСТИ

Резюме

Корреляция магнитной восприимчивостью красноцветных слоев в Литве – новый и сравнительно дешевый метод исследования. Образцы нижнего триаса для исследования магнитной восприимчивости были отобраны из трех буровых скважин Литвы и одной в Калининградской области (Россия). Магнитная восприимчивость была изменена у 687 образцов; построены диаграммы магнитной восприимчивость–глубина. При наличии данных магнитной

восприимчивости в буровой скважине Владимирово-1 (стратотипе отложений нижнего триаса в Балтийском регионе) мы можем сравнивать данные этой скважины с таковыми данными для буровых скважин Галздонай-1, Жвялсенай-8 и Кярнай-1. Результат исследования – новая стратиграфическая корреляция нижнего триаса в Западно-Балтийском регионе. Ранее предполагалось, что все

триасовые отложения в буровых скважинах Жвялсенай-8 и Кярнай-1 относятся к Неманской свите, но новые данные указывают в триасовых отложениях буровых скважин Жвялсенай-8 и Кярнай-1 (и во всей северо-западной части Литвы) на Неманскую и Палангскую свиты. В картах распространения свит область и Палангской свиты в северной части Литвы следует отнести к Неманской свите.