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The Upper Jurassic of the Volga basin: ammonite biostratigraphy and occurrence of organic-carbon rich facies. Correlations between boreal-subboreal and submediterranean provinces

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ABSTRACT

A detailed litho-biostratigraphic succession of the Upper Jurassic deposits of the middle Volga basin is described using six sections, including the lectostratotype of the Volgian. A new biostratigraphic scheme, displaying nineteen ammonite zones, is completed for the Russian Platform. Many biostratigraphic equivalencies between the Russian Platform and both the boreal-subboreal and the submediterranean provinces are proposed and discussed. Seven common horizons (*Pictonia densicostata, Pictonia baylei, Orthaspidoceras lallierianum, Aspidoceras caletanum, Aulacostephanus contejeani, Aulacostephanus yo* and *Aulacostephanus autissiodorensis*) are recognized for the Kimmeridgian Stage, that allow a remarkably precise correlation between the Russian Platform and the western european area. The equivalencies between Volgian, Portlandian and Tithonian are discussed. Correspondences can be only suggested by affinities of the endemic russian ammonites and the boreal faunas. Up to now, the local scheme appears still necessary. Bulk geochemical characterization of the Upper Jurassic series from the Russian Platform shows six main intervals with high organic content (Corg. >10%) and good petroleum potentials. Nevertheless, the stratigraphical distribution of black shales of the Russian Platform is different from those of the Kimmeridge Clay Formation. This clearly indicates that oil shale bands cannot be taken as marker beds at a large scale.

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RÉSUMÉ

Le Jurassique supérieur du bassin de la Volga: biostratigraphie des ammonites et distribution des faciès riches en carbone organique. Corrélations entre les provinces boréale-subboréale et subméditerranéenne.

Une description litho-biostratigraphique détaillée des dépôts du Jurassique supérieur de la moyenne vallée de la Volga est établie à partir de six coupes, dont celle du lectostratotype du Volgien. Une nouvelle succession des faunes d'ammonites, comprenant dix-neuf zones, est proposée pour la plate-forme russe. De nombreuses corrélations entre les échelles biostratigraphiques de la plate-forme russe et celles des provinces boréale-subboréale et subméditerranéenne sont proposées et discutées. Sept horizons (*Pictonia densicostata, Pictonia baylei, Orthaspidoceras lallierianum, Aspidoceras caletanum, Aulacostephanus contejeani, Aulacostephanus yo* et *Aulacostephanus autissiodorensis*) sont communs pour le Kimméridgien, ce qui permet des corrélations très précises entre la plate-forme russe et l'Europe occidentale. Les équivalences entre Volgien, Portlandien et Tithonien sont discutées. Des correspondances peuvent juste être suggérées compte tenu des affinités entre les faunes endémiques russes et les faunes boréales. L'utilisation d'un schéma biostratigraphique local est encore nécessaire à ce niveau de l'étude. La caractérisation géochimique globale de la série du Jurassique de la plate-forme russe montre six intervalles principaux d'enrichissement en matière organique (Corg. > 10%), avec d'excellents potentiels pétroliers. La distribution stratigraphique des black shales de la plate-forme russe est différente de celle des principaux intervalles riches en matière organique de la Formation de Kimmeridge Clay. Ceci indique clairement que ces "bandes organiques" ne peuvent être utilisées comme des marqueurs lithostratigraphiques à une grande échelle.

INTRODUCTION

During Upper Jurassic, precise stratigraphical correlations present many difficulties because of the well known provincialism of ammonite faunas. They become acute progressively from the middle Oxfordian to the Tithonian, and it is necessary to separate schemes of standard ammonites zones for each province and to describe the succession that are to be correlated.

In the Russian Platform, the dominant faunas present boreal or sub-boreal affinities during the Oxfordian and lower Kimmeridgian times. Progressively, endemic ammonites occur in upper Kimmeridgian and in the Volgian faunal sequence.

Correlations with the primary standard of reference of the submediterranean province are the most imprecise. In the recent compilation of the parallel ammonites scales for tethyan northern margin (CARIOU *et al.*,1997; HANTZPERGUE *et al.*, 1997; GEYSSANT, 1997), the equivalence with russian faunal sequences was not taken into consideration. On the contrary, the faunal affinities between Oxfordian and/or Kimmeridgian of the Russian Platform allow best correlations with boreal and sub-boreal provinces. But the "Volgian province" named by NIKITIN (1881a) for the condensed and incomplete uppermost Jurassic sequences require a local faunal scheme. The established ammonite succession in the middle Volga basin should provide useful alternative standard of reference in an area in which another standard cannot be easily applied.

Though most of the sedimentary rocks contain dispersed organic matter from different origins, only a few of them can be considered as organic-rich (> 5% Corg.). Those having a high amount of marine organic matter (> 10 % Corg.) appropriate to generate hydrocarbons and presenting a high degree of immaturity can be considered as "oil shales". Such facies are widespread distributed in the Upper Jurassic succession of the Russian Platform.

The purpose of this paper is to precise the litho-biostratigraphic succession of Upper Jurassic of the Russian Platform, to propose correlations with other Late Jurassic ammonite zonations and to situate the black shales deposits in the stratigraphic framework in order to check their possible synchronicity with the main organic-rich intervals from the North Sea area.

SECTIONS

Five sections were studied in the Moscow basin and the Ulyanovsk-Saratov trough along the Volga River (Fig. 1). The precise location of each section is given in Fig. 2:

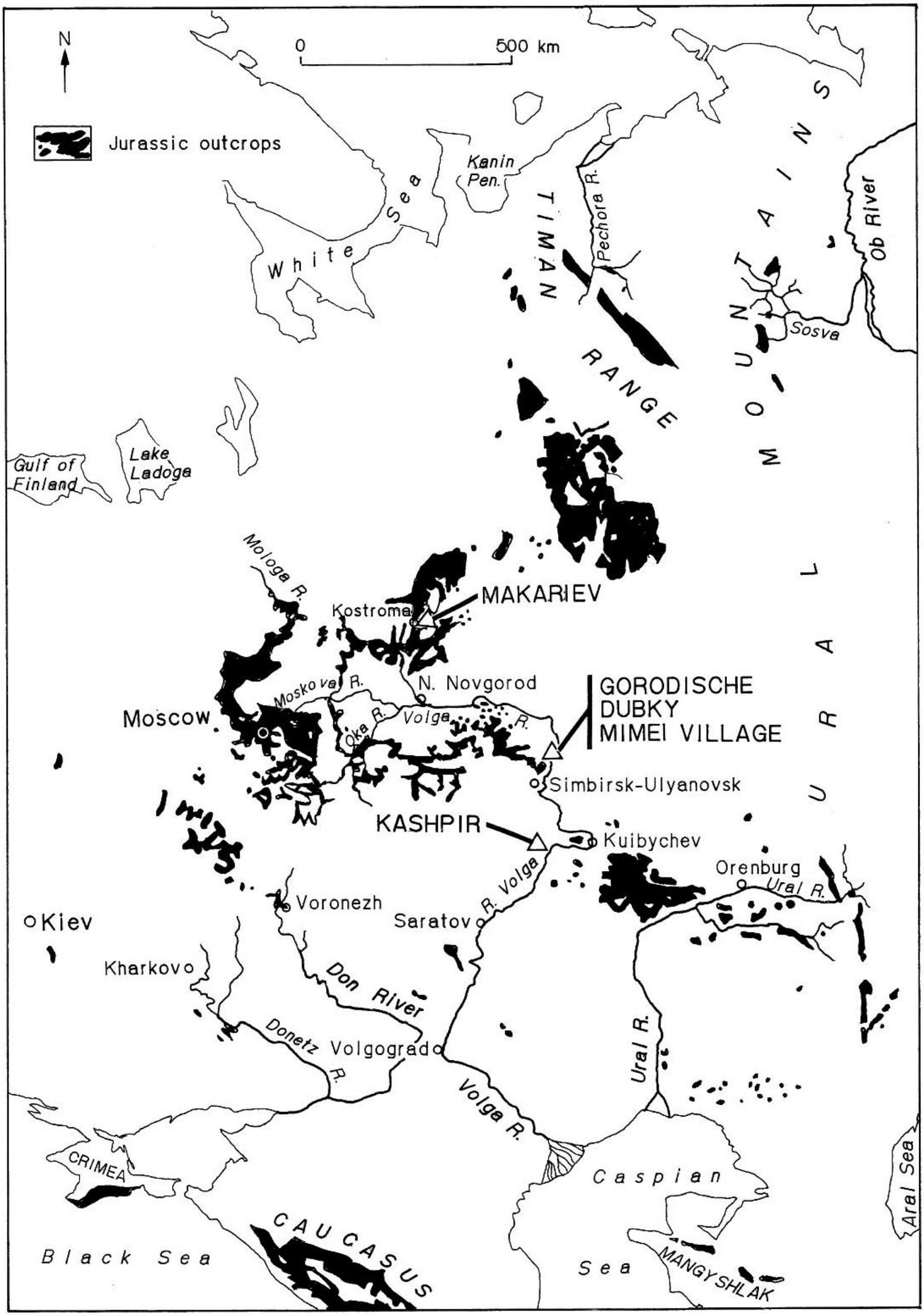

FIG. 1.— Jurassic outcrops of the Russian Platform and location of the studied sections.

FIG. 1.— Affleurements jurassiques sur la plate-forme russe et localisation des coupes éudiées.

— the Oxfordian deposits are detailled in the sections described by NIKITIN (1884) near the town of Makariev on the Unzha River (Fig. 2A). They consist of 5.90 m grey to dark clays with a characteristic horizon of bituminous shales in the middle part and phosphatic pebbles in the upper part. The Makariev section ends with the base of the Kimmeridgian Stage;

— the Kimmeridgian crops out on the waterside of the Kuibyshev reservoir (Volga River, 25 km north of the town of Ulyanovsk), north-east of Undory, between Dubky and Mimei localities (Fig. 2B). It is a thick alternance (54 m and visual gap) of marls and argillaceous limestones containing only one black shales horizon;

— the Volgian Formation are studied in the shore of the Kuibyshev reservoir, between Gorodische village and Dubky locality (Undory village, Fig. 2B). This section corresponds to the Volgian lectostratotype proposed by GERASSIMOV & MIKHAILOV (1966). The upper Volgian Formation is also described in Kashpir, directly south of Syzran, on the Kuibyshev reservoir (Fig. 2C). It corresponds to 18 m of terrigenous deposits, argillaceous in the lower part and sandy in the upper part, with intercalations of four major black shales horizons.

BIOSTRATIGRAPHICAL ELEMENTS

Ammonites were collected bed by bed which allow to characterize the faunal succession for the Upper Jurassic of the middle Volga basin. The observed scheme shows three major biogeographic influences and requires the use of three different zonal scales:

— the Oxfordian Zones are used throughout the boreal province which extends from northern Britain to Greenland through Spitzbergen into the Russian Platform. This scheme is based on Cardioceratids faunas;

— the Kimmeridgian zonal scheme is that of subboreal province which extends from southern Britain across Poland and the middle Volgian basin. Aulacostephanids are the dominant elements. Endemic ammonites of the Franco-German Bioma (HANTZPERGUE, 1989) occur in this subboreal faunal sequence and are common elements between Russian and western european series.

The endemic Volgian ammonites belong to a biogeographic unit which extends from northern Siberia, Russian Platform and Poland across the circum-Arctic shelf, including Barents shelf and northern Canada. This faunal sequence can be compared to the English zonal standard based on boreal Perisphinctids. The correlations with the Tithonian stage are hypothetical (GEYSSANT, 1997); only the genus *Gravesia* allows, according to MESEZHNIKOV *et al.* (1984) an equivalence between the base of the Submediterranean Tithonian and the lowermost beds of the "English upper Kimmeridgian".

ORGANIC MATTER DATA

All the 175 collected rock-samples were open air-dried and crushed in a metallic mortar to obtain a fine (2 μm) powder. Calcium carbonate content (% $CaCO_3$) was measured using a calcimetric bomb. The total carbon content (% Ctot.) was measured using a WR 12 LECO analyser. The organic carbon content (% Corg.) is estimated as the difference between total carbon and mineral carbon, assuming that all the mineral carbon is represented by pure calcite. The C org. concentration describes the quantity of organic carbon, although it should be kept in mind that organically bound hydrogen, oxygen, nitrogen and sulphur can contribute up to 50% of the total sedimentary organic matter. In immature samples, 1 wt% C org. corresponds to 1.5 to 2.0 wt% organic matter. The source and thermal maturation of the organic matter were estimated on 65 samples using a Rock-Eval instrument (ESPITALIÉ *et al.*, 1985-86).

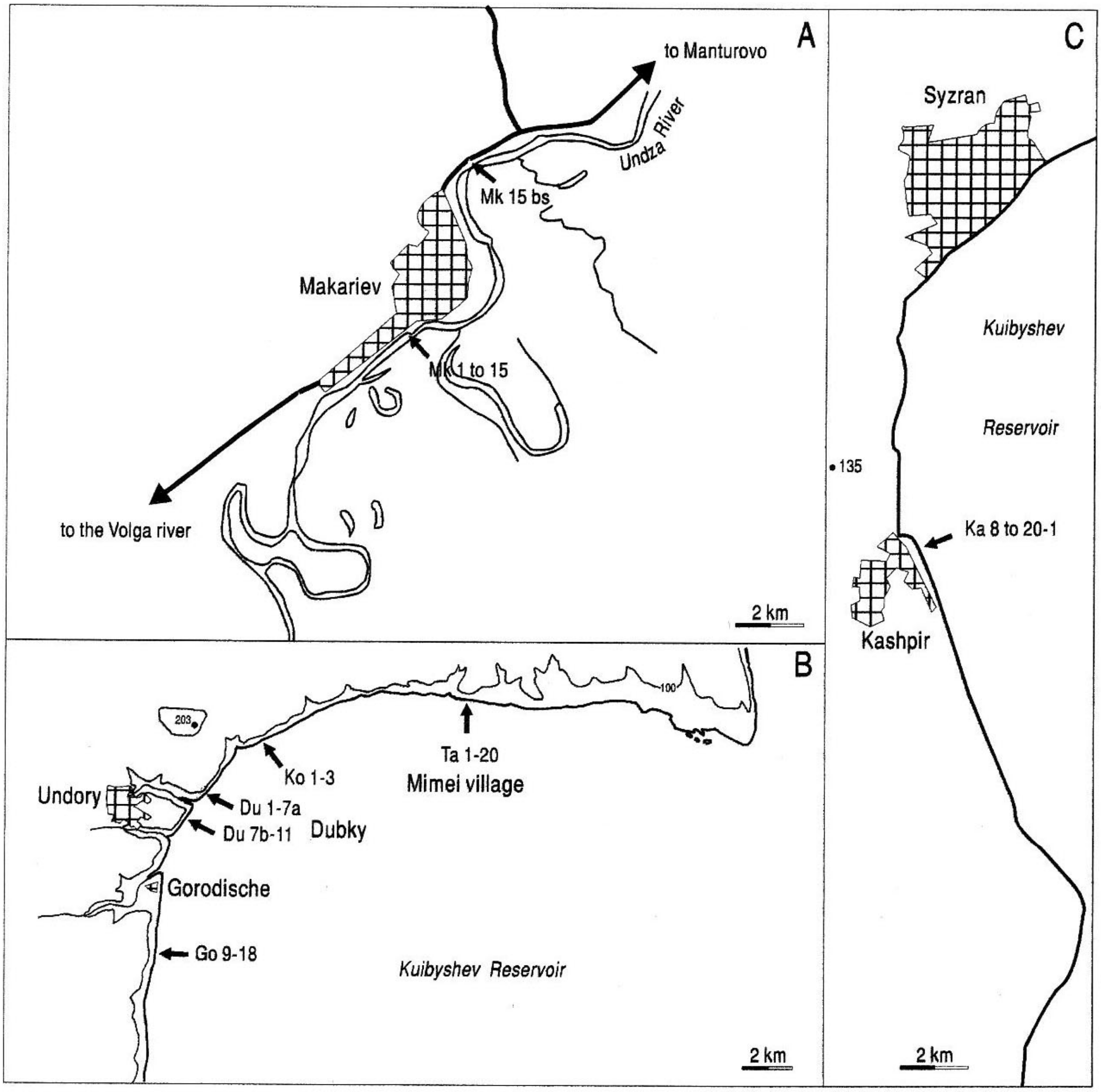

FIG. 2.— Precise location of the studied sections.

FIG. 2.— Localisation précise des coupes étudiées.

UPPER JURASSIC SYNTHETIC SECTION OF THE VOLGA BASIN

OXFORDIAN: MAKARIEV SECTION (MK) (Fig. 3)

LOWER OXFORDIAN

Cordatum Zone d'ORBIGNY (1852).

Mk 16- Compact grey clays, highly bioturbated, showing a 10 to 20 cm-thick bedding with planar surfaces. Centimetric phosphatic nodules are present, and large pieces of wood occur at 20 cm from the bottom. *Pleuromia* sp., *Dentalium* sp., *Astarte* sp., *Entolium* sp., *Nuculoma* sp., *Oxytoma* sp., *Grammatodon* sp., rhynchonellids, belemnites and *Cardioceras (Cardioceras)* gr. *cordatum* (Sow.), *Cardioceras* sp., *Perisphinctes* sp. 1.40 m.

MIDDLE OXFORDIAN

Densiplicatum Zone SYKES (1975) and Tenuiserratum Zone CARIOU (1966).

Mk 15- compact grey clays, bioturbated, starting with a 10 to 15 cm-thick layer rich in glauconite and containing a lot of reworked and non-oriented belemnites. The boundary with the previous unit is underlined by a thin level with crushed ammonites. A lumachellic bed with ammonites, belemnites, gastropods (*Pleurotomaria* sp.) and bivalves (*Gryphaea dilatata, Cosmetodon* sp.) occurs 40 cm below the top. The top of this unit is marked by a yellowish to greenish 10 cm-thick layer of argillaceous pyritic sand with belemnites. *Cardioceras (Subvertebriceras) densiplicatum* Boden, *Cardioceras (Plasmatoceras) tenuistriatum* Borissiak, *Cardioceras (Plasmatoceras) popilaniense* Boden, *Cardioceras (Subvertebriceras) zenaidae* Ilov., *Cardioceras (Plasmatoceras) tenuicostatum* (Nik.), *Cardioceras (Maltoniceras) kokeni* Boden, *Cardioceras* cf. *mauntjoi* Freb. and in upper part: *Cardioceras (Subvertebriceras) zenaidae* Ilov., *Cardioceras (Cawtoniceras) tenuiserratum* (Oppel), *Perisphinctes (Arisphinctes)* gr. *plicatilis* (Sow.). 1.80 m.

UPPER OXFORDIAN

Glosense Zone SYKES (1975).

— Ilovaiskii Subzone SYKES (1975).

Mk 14- finely laminated black shales, with some planar traces (trails ?) at the bottom. Gastropods (*Aporrhais*, *Dicroloma*), bivalves (*Entolium* sp.) and ammonites: *Amoeboceras ilovaiskii* (Sok.), *Amoeboceras alternoides* (Nik.), Perisphinctidae ind. 0.12 m.

Mk 13- black bioturbated clays (Chondrites) with a thin layer of crushed ammonites, bivalves and gastropods at 2 cm from the base. Rare pieces of crinoids at the top. *Amoeboceras ilovaiskii* (Sok.), *Amoeboceras alternoides* (Nik.), Perisphinctidae ind. 0.15 m.

Mk 12- grey silty clays with *Trautscholdia cordata* and debris of ammonites: *Amoeboceras alternoides* (Nik.), *Amoeboceras transitorium* Spath, *Amoeboceras* cf. *glosense* (Bigot & Brasil), *Amoeboceras ilovaiskii* (Sok.). 0.30 m.

Serratum Zone SYKES (1975).

— Koldeweyense Subzone Sykes (1975).

Mk 11d- compact grey clays with belemnites: *Pachytheutis panderiana* (d'Orb.), *Hibolites* sp. and ammonites: *Amoeboceras alternoides* (Nik.), *Amoeboceras* cf. *damoni* Spath, *Amoeboceras* cf. *koldeweyense* Sykes & Callomon, *Amoeboceras ilovaiskii* (Sok.). 0.30 m.

Mk 11c- greenish clays having a yellowish to rust-coloured alteration, containing pyritic and phosphatic nodules, glauconite, belemnites and ammonites: *Amoeboceras koldeweyense* Sykes & Callomon, *Amoeboceras* gr. *serratum* (Sow.), *Amoeboceras* cf. *talbejense* Kal. & Mesezhn. 0.10 m.

— Serratum Subzone SYKES (1975).

Mk 11b- compact grey clays with: *Amoeboceras* cf. *ovale* (Quenst.), *Amoeboceras* cf. *tuberculatoalternans* (Nik.), *Amoeboceras* gr. *serratum* (Sow.). 0.10 m.

Mk 11a- greenish clays having a yellowish to rust-coloured alteration, containing bivalves (*Buchia*, *Meleagrinella*, *Astarte*) and belemnites. 0.08 m.

Mk 10b- grey clays becoming glauconitic to the top with belemnites, bivalves (*Trautscholdia cordata*), and *Amoeboceras* cf. *ovale* (Quenst.), *Amoeboceras* gr. *serratum* (Sow.). The upper surface is bioturbated and burrows filled by the glauconitic clays. 0.20 m.

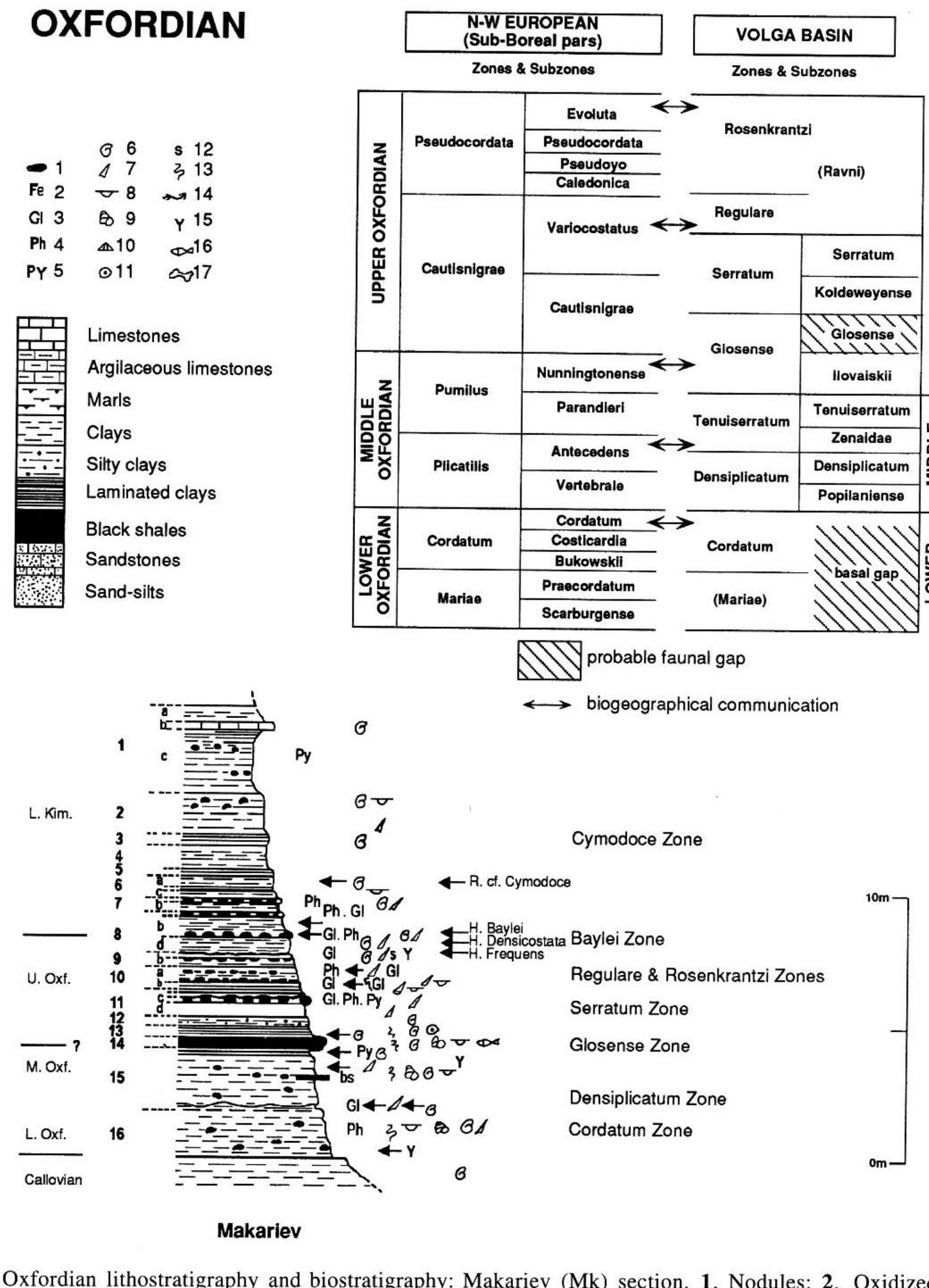

FIG. 3.— Oxfordian lithostratigraphy and biostratigraphy: Makariev (Mk) section. **1**, Nodules; **2**, Oxidized surface; **3**, Glauconite; **4**, Phosphate; **5**, Pyrite; **6**, Ammonite; **7**, Belemnite; **8**, Bivalve; **9**, Gastropod; **10**, Brachiopod; **11**, Crinoid; **12**, Serpule; **13**, Bioturbation; **14**, Trail; **15**, Larges wood fragments; **16**, Fish; **17**, Vertebrates remains.

*FIG. 3.— Lithostratigraphie et biostratigraphie de l'Oxfordien : coupe de Makariev (Mk). **1**, Nodules ; **2**, Surface oxydée ; **3**, Glauconie ; **4**, Phosphate ; **5**, Pyrite ; **6**, Ammonite ; **7**, Bélemnite ; **8**, Bivalve ; **9**, Gastéropode ; **10**, Brachiopode ; **11**, Crinoïde ; **12**, Serpule ; **13**, Bioturbation ; **14**, Piste ; **15**, Grands fragments de bois ; **16**, Poisson ; **17**, Restes de vertébrés.*

Regulare and Rosenkrantzi Zones SYKES (1975).

Mk 10a- grey clays with phosphatic pebbles, becoming intensely biotubated with reworked belemnites at the top. *Amoeboceras* cf. *ovale* (Quenst.), *Amoeboceras tuberculatoalternans* (Nik.), *Amoeboceras* cf. *lineatum* (Quenst.), *Amoeboceras* gr. *serratum* (Sow.), *Amoeboceras gerassimovi* Kal. & Mesezhn., *Amoeboceras* cf. *freboldi* Spath, *Amoeboceras leucum* Spath. 0.40 m.

Mk 9b- grey clays with ammonites, belemnites and some phosphatic concretions at the top. *Amoeboceras* cf. *lineatum* (Salf.). 0.40 m.

Mk 9a- glauconitic clays with phosphatic concretions, belemnites, bivalves and serpulids. Floated wood appears on the upper surface of this unit. 0.05 m.

Mk 8d- grey clays with belemnites and ammonites: *Amoeboceras* cf. *lineatum* (Salf.) and *Ringsteadia* cf. *frequens* Salf. at the top. 0.50 m.

KIMMERIDGIAN (Fig. 4)

LOWER KIMMERIDGIAN: MAKARIEV (MK) AND MIMEI VILLAGE (TA) SECTIONS

Baylei Zone SALFELD (1913).

Mk 8c- glauconitic and ferrugineous clays with phosphatic nodules, bivalves (*Nuculoma* sp.), belemnites and ammonites: *Pictonia densicostata* Salfeld. 0.05 m.

Mk 8b- grey clays with ammonites (*Pictonia baylei* Salfeld) appearing at 20 cm from the base. *Amoeboceras (Amoebites)* cf. *kitchini* (Salfeld), *Amoeboceras* sp., *Desmosphinctes* cf. *mniovnikensis* Nik. 0.50 m.

Mk 8a- altered glauconitic clays with oyster fragments, phosphatic nodules and small crystal of (secondary ?) gypsum. 0.05 m.

Cymodoce Zone DOUVILLÉ (1881).

Mk 7b- dark laminated clays with belemnites, fish-scales, gastropods (*Aporrhais*) and bivalves (*Loripes* sp., *Nannogyra* sp.), *Perisphinces* sp. juv. 0.50 m.

Mk 7a- glauconitic clays with nodules and large crushed ammonites and oysters. 0.05 m.

Mk 6c- grey clays having a cubic cutting up. 0.20 m.

Mk 6b- dark laminated clays with bivalves (*Loripes* sp.). 0.10 m.

Mk 6a- grey clays with large shells of ammonites: *Rasenia* cf. *uralensis* (d'Orb.) and *Rasenia* cf. *cymodoce* (d'Orb.). 0.30 m.

Mk 5- dark laminated clays, *Amoeboceras (Amoebites)* gr. *kitchini* (Salf.) 0.20 m.

Mk 4- clays having a cubic cutting up and containing large crushed shells of ammonites (*Amoeboceras* sp.) and bivalves (*Nuculoma* sp. ind.). 0.70 m.

Mk 3- dark laminated clays with *Rasenia* sp. 0.30 m.

Mk 2- grey clays, deeply altered toward the top, with rare ammonites, belemnites at the base, bivalves (*Nuculoma* sp.) and phosphatic nodules at the top. 1.10 m.

Mk 1c- grey clays, bioturbated near the bottom, with numerous shelly debris (ammonites, bivalves) at the middle part. Centimetric limestone nodules appear 30 cm below the top. *Amoeboceras* cf. *cricki* (Salf.). 1.80 m.

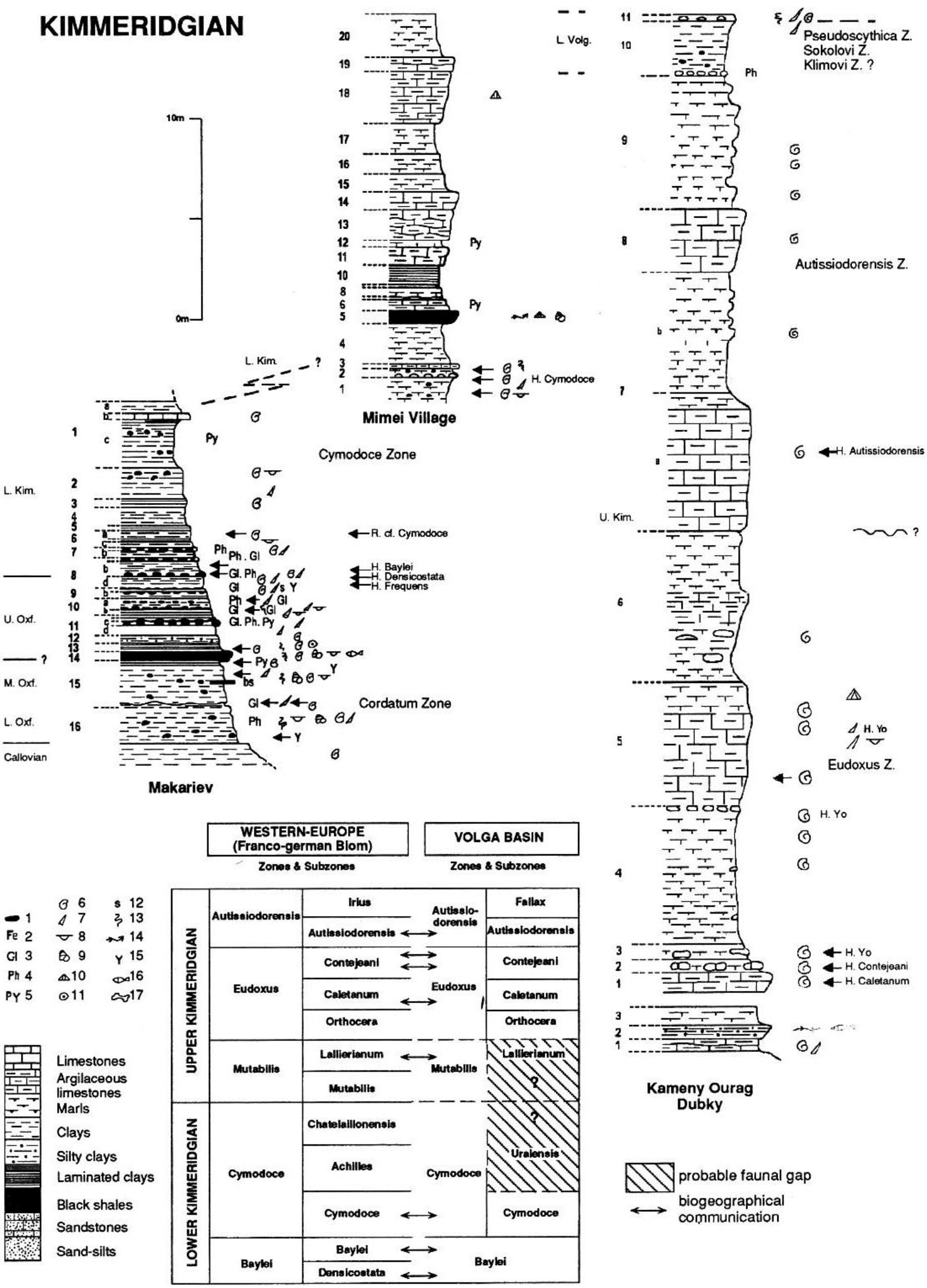

FIG. 4.— Kimmeridgian lithostratigraphy and biostratigraphy: Makariev (Mk), Mimei village (Ta), Dubky (Du) and Kameny Ourag (KO) sections.

FIG. 4.— Lithostratigraphie et biostratigraphie du Kimméridgien : coupes de Makariev (Mk), Mimei village (Ta), Dubky (Du) et Kameny Ourag (KO).

Mk 1b- grey micritic limestone with a rust-coloured alteration in the middle part containing *Rasenia* cf. *uralensis* (d'Orb.) at the top. 0.20 m.

Mk 1a- clays, deeply altered by the proximity of soil. 0.40 m.

Hiatus.

Ta 1- grey marls with phosphatic nodules. At the bottom, large debris of wood. Bivalves: *Buchia concentrica*, *Malletia* sp., and ammonites: *Rasenia* cf. *uralensis* (d'Orb.), *Amoeboceras* sp. At the top, ammonites, *Rasenia* cf. *cymodoce* (d'Orb.) and belemnites. 2.00 m.

Ta 2- grey marls with phosphatic nodules and ammonites (Perisphinctids). The base is marked by a more or less continuous level of whitish nodules. 0.30 m.

Ta 3- grey argillaceous limestone, intensely bioturbated. 0.20 m.

Ta 4- grey marls becoming darker to the top. 1.60 m.

Ta 5- brownish finely laminated black shales with planar traces (trails ?) and rare fauna of brachiopods and gastropods (*Meleagrinella, Aporrhais* sp.). 0.50 m.

Ta 6- dark-grey platy argilaceous limestones with pyritic nodules. 0.45 m.

Ta 7- dark-grey laminated marls. 0.03 m.

Ta 8- light-grey marls. 0.40 m.

Ta 9- greyish to brownish laminated clays. 0.10 m.

Ta 10- dark-grey laminated clays. 0.70 m.

Ta 11- light-grey argillaceous limestones. 0.75 m.

Ta 12- marls more or less laminated. 0.25 m.

Ta 13- grey to beige argillaceous limestones. 1.10 m.

Ta 14- compact beige argillaceous limestones. 0.70 m.

Ta 15- grey to beige platy marls. 0.70 m.

Ta 16- grey marls. 0.80 m.

Ta 17- compact beige marls. 1.10 m.

Ta 18- light-beige argillaceous limestones containing rare *Lingula* sp. 2.00 m.

Ta 19- light-grey argillaceous limestones. 0.50 m.

Ta 20- marls, deeply altered due to the proximity of soil. 1.50 m.

Hiatus.

Upper Kimmeridgian: Dubky and Kamenyi Ourag sections (Du and Ko)

Hiatus.

Eudoxus Zone Neumayr (1873).

Ko 1- grey argillaceous limestones with belemnites and ammonites: *Pararasenia hybridus* Ziegler, *Aspidoceras caletanum* (Opp.). 0.50 m.

Ko 2- greyish to greenish silty clays with planar burrows, numerous fish-scales and remains. 0.40 m.

Ko 3- grey marls. 1.00 m.

Du 1- light-grey argillaceous limestones containing some ferrugineous nodules with belemnites and ammonites: *Aulacostephanus eudoxus* (d'Orb.), *Aspidoceras caletanum* (Opp.), *Aspidoceras* gr. *longispinum* (Sow.), and *Amoeboceras* sp. 0.60 m.

Du 2- marls containing light-grey calcareous lenses and numerous limonitic ammonites: *Aulacostephanus contejeani* (Thur.), *Aspidoceras quercynum* Hantzpergue, and *Tolvericeras sevogodense* (Contini & Hantzpergue). 0.50 m.

Du 3- marls containing light-grey calcareous lenses and numerous limonitic ammonites: *Aulacostephanus yo* (d'Orb.), *Aspidoceras* gr. *quercynum* Hantzpergue. 0.50 m.

Du 4- light-grey marls containing some calcareous nodules and small belemnites. A 50 cm thick more clayey bed lies 2 m from the base. Ammonites, *Aspidoceras* sp. and *Aulacostephanus* cf. *yo* (d'Orb.) appear at 3 m and 4 m. The top of this units is marked by a layer of calcareous nodules. 4.00 m.

Du 5- beige massive argillaceous limestones, with rare phosphatic nodules, becoming grey and marly within the uppermost 1 m. Aptychus (*Laevaptychus*), belemnites, brachiopods (Zeillerids), bivalves (*Loripes*) and large pyritic disc containing ammonites: *Aspidoceras* sp. and *Aulacostephanus* cf. *yo* (d'Orb.). 4.00 m.

Du 6- grey to beige bioturbated marls and argillaceous limestone with calcareous nodules containing ammonites, *Tolvericeras* gr. *sevogodense* (Contini & Hantzpergue). 5.00 m.

Autissiodorensis Zone ZIEGLER (1961).

Du 7a- beige argillaceous limestones becoming marly in the topmost 50 cm. *Amoeboceras* sp., *Aulacostephanus autissiodorensis* (Cotteau), *Aulacostepanus kirghisensis* (d'Orb.), *Aulacostephanus volgensis* (d'Orb.), *Aulacostephanus undorae* (Pavl.), *Amoeboceras (Nannocardioceras) volgae* (Pavl.), *Amoeboceras (Nannocardioceras) subtilicostatum* (Pavl.), *Sutneria* sp., *Virgataxioceras* sp. 4.50 m.

Du 7b1- grey to grey-greenish marls with phosphatic nodules and pyritic disc. 2.00 m.

Du 7b2- alternation of dark-grey to light-grey marls with ammonites: *Aulacostephanus autissiodorensis* (Cotteau), *Aulacostephanus kirghisensis* (d'Orb.), *Aulacostephanus volgensis* (d'Orb.), *Aulacostephanus undorae* (Pavl.), *Virgataxioceras fallax* (Ilov.). 2.00 m.

Du 8- grey to light-beige argillaceous limestone with ammonites: *Aulacostephanus autissiodorensis* (Cotteau), *Aulacostephanus kirghisensis* (d'Orb.), *Aulacostephanus volgensis* (d'Orb.), *Aulacostephanus undorae* (Pavl.), *Virgataxioceras fallax* (Ilov.) 2.20 m.

Du 9- alternation of dark-grey to light-grey marls with ammonites concentrated at the base of dark-grey beds, *Aulacostephanus autissiodorensis* (Cotteau), *Virgataxioceras fallax* (Ilov.), small *Aspidoceras* (?) and *Sutneria* sp. 4.50 m.

VOLGIAN (Fig. 5)

LOWER VOLGIAN: DUBKY SECTION (DU)

Klimovi Zone MIKHAILOV (1962 a).

Ammonite fauna, after MESEZHNIKOV *et al.* (1984): *Ilowaiskya klimovi* (Ilov & Flor.), *Gravesia* cf. *gigas* (Zieten), *Gravesia* cf. *gravesiana* (d'Orb.) *Neochetoceras* cf. *steraspis* (Opp.), *Glochiceras* cf. *lithographicum* (Opp.) and *Sutneria* cf. *subeumela* (Schneid).

Du 10a- grey clay with phosphatic nodules at the base. *Ilowaiskya klimovi* (Ilov.), *Neochetoceras* sp., *Glochiceras* sp. 0.80 m.

Sokolovi Zone ILOVAISKY & FLORENSKY (1941).

Ammonite fauna, after MESEZHNIKOV (1988): *Ilowaiskya sokolovi* (Ilov. & Flor.), *Ilowaiskya pavida* (Ilov. & Flor.), *Sutneria* sp., *Haploceras* cf. *elimatum* (Opp.), *Glochiceras* (*Paralingulaticeras*) cf. *lithographicum* (Opp.), *Glochiceras* (*Paralingulaticeras*) cf. *parcevali* (Font.)

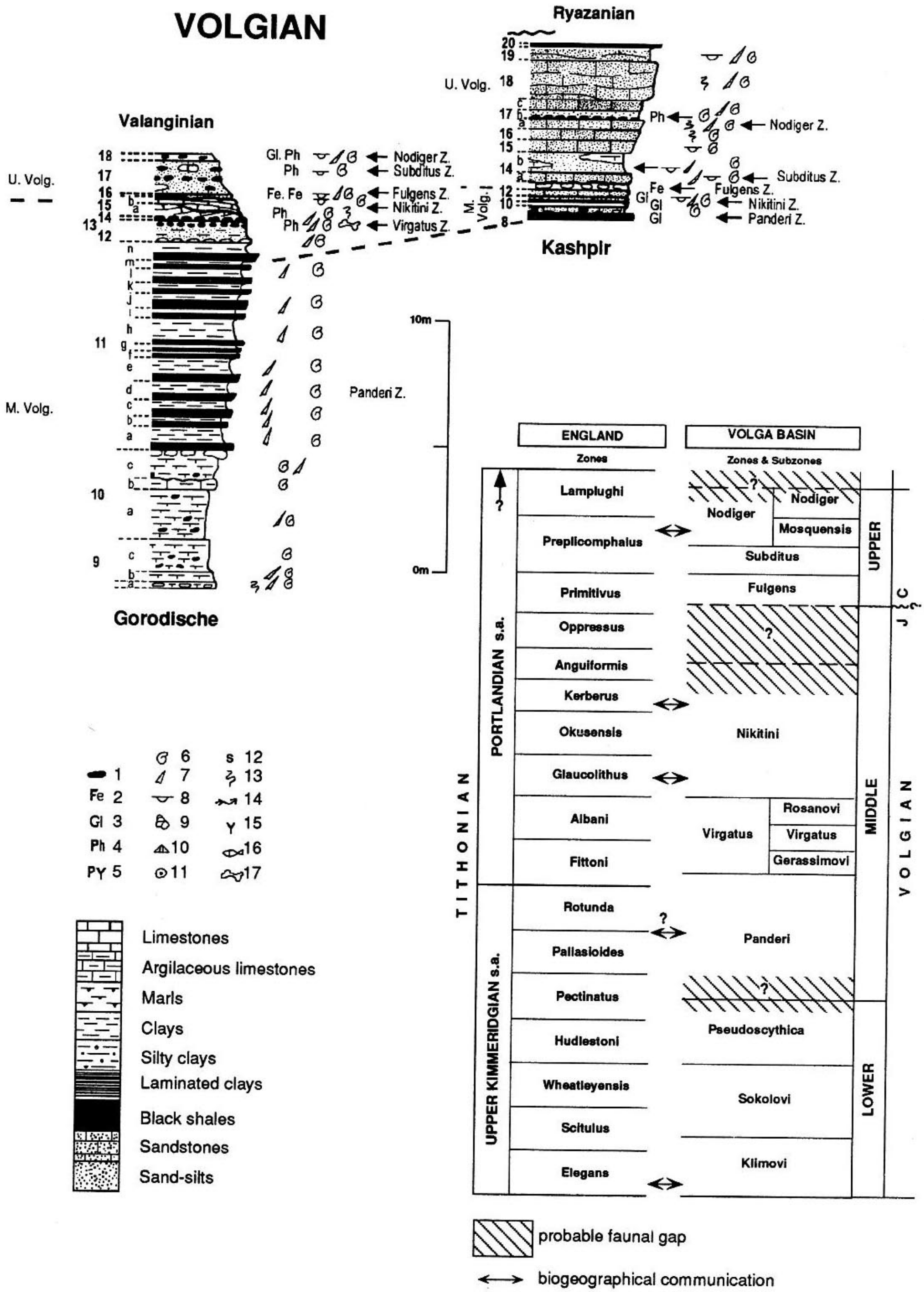

FIG. 5.— Volgian lithostratigraphy and biostratigraphy: Dubky (Du), Gorodische (Go) and Kashpir (Ka) sections.

FIG. 5.— Lithostratigraphie et biostratigraphie du Volgien : coupes de Dubky (Du), Gorodische (Go) et Kashpir (Ka).

Du 10b- dark-grey clay with small carbonates nodules, *Ilowaiskya sokolovi* Ilov., *Ilowaiskya pavida* Ilov. 1.00 m.

Pseudoscythica Zone ILOVAISKY & FLORENSKY (1941).

Ammonite fauna, after MESEZHNIKOV (1988): *Ilowaiskya schaschkovae* (Ilov. & Flor.), *Ilowaiskya pseudoscythica* (Ilov. & Flor.), *Pectinatites ianschini* (Ilov.), *Pectinatites tenuicostatus* Mikhailov, *Glochiceras* sp., *Sutneria* sp., *Haploceras* sp.

Du.10c- grey clay with ammonites and belemnites concentrated at the top, *Ilowaiskya pseudoscythica* Ilov., *Ilowaiskya pavida* Ilov. 0.80 m.

MIDDLE VOLGIAN: GORODISCHE (GO) AND KASHPIR(KA) SECTIONS

Panderi Zone ROZANOV (1906).

Ammonite fauna, after MESEZHNIKOV *et al.* (1984) and MITTA (1993): *Dorsoplanites dorsoplanus* (Vischniakoff), *Dorsoplanites panderi* (d'Orb.), *Pavlovia pavlovi* (Michalski), *Zaraiskites scythicus* (Vischniakoff), *Zaraiskites michalskii* Mitta, *Zaraiskites quenstedti* (Rouillier & Fahrenkohl), *Zaraiskites tschernyschovi* (Michalski), *Zaraiskites zarajskensis* (Michalsky), *Acuticostites acuticostatus* (Michalski), *Acuticostites bitrifurcatus* Mitta.

Go 9a- grey marls, intensely bioturbated (*Chondrites*), with pyrite concretions. Perforated calcareous nodules occur at the base, ammonites and belemnites at the top. 0.20 m.

Go 9b- dark-grey marls with ammonites and belemnites. 0.25 m.

Go 9c- grey marls, intensely bioturbated, with phosphatic nodules, belemnites and ammonites. 1.00 m.

Go 10a- grey marls, intensely bioturbated, with phosphatic nodules, belemnites and ammonites. 1.50 m.

Go 10b- nodular argillaceous limestones with ammonites. 0.15 m.

Go 10c- bioturbated grey marls being dark-grey in the middle part with ammonites, belemnites and phosphatic nodules. Within the last 20 cm, a white argillaceous millstone level is visible. 0.85 m.

Go 11- alternation of black shales and dark-grey calcareous clays with ammonites, belemnites, rare bivalves and pyritic nodules. Toward the top, the clays appear lighter in colour: grey to brownish with some yellowish level due to alteration of pyritic layer (jarosite ?). This unit is subdivided into 14 decimetric black shale/calcareous clays doublets. 6.10 m.

Virgatus Zone ROUILLIER (1845).

Ammonite fauna, after MESEZHNIKOV *et al.* (1984) and MITTA (1993): *Virgatites virgatus* (Buch), *Virgatites* cf. *sosia* (Vischniakoff), *Virgatites pallasianus* (d'Orb.), *Virgatites pusillus* (Mich.), *Virgatites gerassimovi* Mitta, *Lomonossovella lomonossovi* (Vischniakoff), *Acuticostites acuticostatus* (Michalski), *Acuticostites bitrifurcatus* Mitta.

Go 12- conglomerate of red to black phosphatic nodules and pebbles, belemnites and ammonites: *Virgatites virgatus* (Buch). 0.10 m.

Go 13- yellowish to greenish argillaceous silts with dispersed phosphatic pebbles and belemnites. 14 cm below the top, phosphatic pebbles, belemnites and vertebrate remains (*Icthyosaurus, Pleisiosaurus*) are concentrated. 0.50 m.

Go 14- conglomerate of black phosphatic pebbles, belemnites and ammonites (*Virgatites virgatus* (Buch)) in a sandy matrix. The top of this unit has an irregular surface. 0.10 m.

Nikitini Zone LAHUSEN (1883).

Ammonite fauna, after Mitta (1993): *Epivirgatites nikitini* (Michalsky), *Epivirgatites bipliciformis* (Nikitin), *Laugeites stschurowskii* (Nikitin), *Laugeites aenivanovi* Mitta, *Lomonossovella lomonossovi* (Vischniakoff).

Go 15- yellowish to greenish argillaceous sands passing laterally to sandstones with ammonites, *Paracraspedites* sp., *Epivirgatites nikitini* (Michalsky), bivalves (*Buchia* sp.) and concentration of belemnites to the top. The upper limit is an undulated oxidised surface with a rust-colour. 0.60 m.

UPPER VOLGIAN: KASHPIR SECTION (KA)

Fulgens Zone NIKITIN (1888).

Ammonite fauna, after GERASIMOV (1969): *Kashpurites fulgens* (Trautschold), *Kashpurites subfulgens* (Nikitin), *Garniericeras catenulatum* (Fischer), *Craspedites okensis* (d'Orb.), *Craspedites nekrassovi* Prigorovski.

Ka 13- brownish to greyish clayey sandstones with calcareous seams containing ammonites, *Kashpurites fulgens* (Trautschold), *Garniericeras catenulatum* (Fischer), belemnites (*Acrotheutis mosquensis*) and bivalves (*Buchia* sp.). At the top of the unit occurs a thin level (2 cm) of strongly ferrugineous carbonate. 0.50 m.

Subditus Zone NIKITIN (1888).

Ammonite fauna after MESEZHNIKOV *et al.* (1984): *Craspedites okensis* (d'Orb.), *Craspedites subditus* (Trautsch.), *Craspedites subditoides* (Nikitin), *Garniericeras catenulatum* (Fischer).

Ka 14a- light-grey fine-grained glauconitic sandstones with belemnites, ammonites and bivalves. 0.25 m.

Ka 14b- light-grey sands poorly cemented with calcareous patches. This unit is rich in ammonites, *Craspedites okensis* (d'Orb.), *Craspedites subditus* (Trautsch.), broken belemnites and *Buchia* sp. 0.60 m.

Ka 15- light-grey fine-grained sandstone with calcareous cement containing ammonites and *Buchia* sp. 0.35 m.

Ka 16- dark-grey bioturbated sandstones with numerous ammonites and bivalves. 0.30 m.

Nodiger Zone NIKITIN (1888).

Ammonite fauna, after GERASIMOV (1969): *Craspedites nodiger* (Eichwald), *Craspedites kaschpuricus* (Trautsch.), *Craspedites parakaschpuricus* Gerassimov, *Craspedites milkovensis* Stremooukhov, *Craspedites kuznetzovi* (Sokolov), *Craspedites mosquensis* Gerassimov, *Garniericeras subclypeiforme* (Milaschevitsch).

Ka 17a- light-grey fine-grained sandstones, strongly bioturbated, with dark-grey burrows, ammonites, *Craspedites nodiger* (Eichwald) and belemnites. 0.35 m.

Ka 17b- fine-grained calcareous sandstones starting by a level containing cm-long phosphatic pebbles and ammonites. 0.20 m.

Ka 17c- light-grey calcareous sandstones with lumachellic lenses rich in belemnites, ammonites and bivalves. 0.30 m.

Ka 18- massive light-grey fine-grained calcareous sandstones, strongly bioturbated, with numerous and non-oriented shells, belemnites and ammonites. 1.10 m.

Ka 19- light-grey to greenish bioclastic sandstones having a nodular appearance. Numerous ammonites: *Craspedites nodiger* (Eichwald), *Craspedites kaschpuricus* (Trautsch.), *Garniericeras subclypeiforme* (Milaschevitsch). 0.40 m.

Ka 20- brown finely laminated black shale overlain by Ryazanian deposits. 0.15 m.

AMMONITES ZONATION AND CORRELATIONS

OXFORDIAN

On the central part of the Russian Platform (middle Volga basin), the Oxfordian stage is characterized by boreal Cardioceratids. This ammonite faunas allow a precise correlation with the standard zonation of the boreal Oxfordian (SYKES & SURLYK, 1976) and with the *Amoeboceras* zonation of the boreal upper Oxfordian (SYKES & CALLOMON, 1979).

The equivalence between sub-boreal and tethyan zonations is yet imperfect: the base of Cordatum Zone is only correlated with the Claromontanus Zone of the tethyan scheme (CARIOU *et al.,* 1997).

In the excellent sections of Makariev, on the Unzha River (NIKITIN, 1884), the Oxfordian shows likely a hiatus of the lower part. The first Oxfordian ammonite faunas is a Cardioceratid assemblage, including *Cardioceras* gr. *cordatum* (Sow.), typical form of the standard Cordatum Subzone (Cordatum Zone). Although the species ranges are not precisely determined, it seems that Bukowskii and/or Gloriosum Subzones, and Costicardia and/or Percaelatum Subzones are included in the basal Oxfordian gap.

The middle Oxfordian Cardiocerartid faunas, dominated in lower part by *C. (Subvertebriceras) densiplicatum* Boden, *C. (Plasmatoceras) popilaniense* Boden, *C. (Subvertebriceras) zenaidae* Ilov. and *C. (Plasmatoceras) tenuistriatum* Borissiak, indicate the Densiplicatum Zone. The occurrence of *C. (Cawtoniceras) tenuiserratum* (Opp.) and *P. (Arisphinctes)* gr. *plicatilis* (Sow.) in upper part of Mk 15 level, suggest the Tenuiserratum Zone. A Tenuiseratum Horizon was defined at the top of the Antecedens Subzone (Plicatilis Zone) of the submediterranean province (CARIOU, 1966; MALINOWSKA, 1966). This unit allows a precise correlation between the top of the boreal middle Oxfordian and the medium part of this substage in Tethyan realm (CARIOU *et al.,* 1997; MESEZHNIKOV, 1988, 1989).

In the upper Oxfordian boreal series, an *Amoeboceras* faunal sequence allows to subdivide this part of the Stage into four zones: Glosense, Serratum, Regulare and Rosenkrantzi Zones (SYKES & SURLYK, 1976). In Makariev sections, the Glosense Zone contains a typical fauna of the Ilovaiskii Subzone. The upper Glosense Subzone is not clearly identified. These boreal unit is approximately equivalent to the lower part of the Submediterranean Bifurcatus Zone (Stenocycloides Subzone, CARIOU *et al.,* 1997). The assemblage of *Amoeboceras ilovaiskii* (Sok.) and *A.* cf. *glosense* (Bigot & Brasil) (Mk 12) possibly indicates the nearby of the Ilovaiskii/Glosense boundary. A hiatus of the Glosense Subzone seems probable.

The Koldeweyense and Serratum Subzones (Serratum Zone) are indicated by the occurrence of their index. The assemblage of different *Amoeboceras* with *A. leucum* Spath and *A. tuberculatoalternans* (Nik.) indicate the upper Oxfordian Regulare and Rosenkrantzi Zones. It should be noted that the ammonite ranges in this section need to be worked out more precisely. The occurrence of *Ringsteadia cuneata* (Trautsch.) (MESEZHNIKOV, 1988) and *R. frequens* Salf. in Mk 8d level indicates the uppermost Oxfordian. This *Ringsteadia* fauna is directly followed by Kimmeridgian *Pictonia* (Mk 8c). Consequently, the Oxfordian/Kimmeridgian boundary can be precisely correlated between Russian Platform and sub-boreal western-european series.

Concerning a possible correlation with tethyan series, an equivalence is suggested between boreal Serratum and Regulare Zones and the tethyan Bifurcarus Zone (CARIOU *et al.*, 1997). The correspondence of the Oxfordian/Kimmeridgian boundary for this two realms is still imprecise. Recent propositions (ATROPS *et al.*, 1993) suggest that the usual tethyan Planula Zone belongs partly or totally into the Kimmeridgian stage.

KIMMERIDGIAN

During the Kimmeridgian, the ammonites provincialism is more pronounced in the north tethyan margin. The Tethyan and Boreal Realms are separated by an intermediate area: the Franco-German Bioma (HANTZPERGUE, 1979, 1989 ; HANTZPERGUE *et al.,* 1997 ; ENAY, 1966, 1980 ; HAUG, 1898). The subboreal province is characterized by Cardioceratids and Aulacostephanids with respectively the genus *Amoeboceras* and *Pictonia*, *Rasenia*, *Aulacostephanus.* In an other hand, the Franco-German Bioma is an overlapping area for the sub-boreal and tethyan faunas but above all, a differentiated area with endemic forms of Aspidoceratids, Aulacostephanids and Perisphinctids (HANTZPERGUE, 1989). The middle Volga Kimmeridgian series show the same particularities and the best biostratigraphical correlations can be made with the Kimmeridgian stage.

The lowermost Russian usual zone, the Evoluta Zone (MESEZHNIKOV, 1988) contains a *Pictonia* fauna. The Densicostata and Baylei Horizons located in Mk 8c-8b levels of Makariev section define the standard Baylei Zone.

The "kitchini beds" (MESEZHNIKOV, 1988) are characterized by *Amoeboceras* faunas with *A. (Amoebites) kitchini* (Salf.) and *A. (Amoebites) cricki* (Salf.). *Rasenia* gr. *cymodoce* (d'Orb.) and *Rasenia* gr. *uralensis* (d'Orb.) occur in Mk 7a-6a levels of the Makariev section. They indicate a Cymodoce Horizon located at the lower part of the Cymodoce Subzone (HANTZPERGUE *et al.,* 1997), and the "Zonovia" uralensis Subzone corresponds probably with the upper part of the standard Cymodoce Zone. Consequently, the classic "*Amoeboceras kitchini* Beds" of the Russian Platform are equivalent or partially equivalent to Baylei and Cymodoce Zones of the western european standard biostratigraphical scale.

The lower Kimmeridgian of middle Volga area is not complete: Makariev and Mimei village outcrops are relatively poor in ammonite faunas and incomplete for the middle and upper part of Cymodoce Zone.

Upper Kimmeridgian is most fully developed on these area, but lower Mutabilis Zone, (equivalent to the Sosvaensis Zone (MESEZHNIKOV, 1988) or to the Acanthicum Zone *auct.*), is no more visible. *Orthaspidoceras liparum* (Opp.) is mentioned by Meseznikov below the lake level of the Kuyibishev reservoir. This ammonite is the dimorphic form of *O. lallierianum* (d'Orb.), index of a Lallierianum Horizon and a Lallierianum Subzone, located at the upper part of the standard Mutabilis Zone (HANTZPERGUE, 1989).

In compensation, the Eudoxus and Autissiodorensis Zones show the most biostratigraphical accuracy. Three western european horizons of the Eudoxus Zone are present in the Dubky section:

— Caletanum Horizon, Caletanum Subzone (HANTZPERGUE, 1979), with *Aspidoceras caletanum* (Opp.), *Aspidoceras* gr. *longispinum* (Sow.), *Aulacostephanus eudoxus* (d'Orb.), *Pararasenia* cf. *hybridus* Ziegler and *Amoeboceras* sp., levels Ko 1-3, Du 1;

— Contejeani Horizon, Contejeani Subzone (HANTZPERGUE, 1979), with *Aspidoceras* gr. *quercynum* Hantzpergue, *Aulacostephanus contejeani* (Thurmann), *Tolvericeras sevogodense* (Contini & Hantzpergue), Du 2 level;

— Yo Horizon, Contejeani Subzone, with *Aulacostephanus yo* (d'Orb.), *Aspidoceras* gr. *quercynum* Hantzpergue, *Aspidoceras* sp. and *Tolvericeras* gr. *sevogodense* (Contini & Hantzpergue), levels Du 3-6.

The Autissiodorensis Zone corresponds to the occurrence of the index *Aulacostephanus autissiodorensis* (Cott.) and its dimorphs, *A. volgensis* (Vischn.), *A. kirghisensis* (d'Orb.), *A. undore* (Pavl.). In the upper part, was defined the Fallax Subzone (MIKHAILOV, 1962 b) with dominant *Virgataxioceras fallax* (Ilov.) constantly accompanied by the zonal index. The Kimmeridgian/Volgian boundary is setting at the last apparition datum of *A. autissiodorensis* (Cott.).

VOLGIAN

The deposits of the "Volgian stage" of the typical region (central part of the Russian Platform) are subdivided into three substages (MIKHAILOV, 1962 a, 1964, GERASIMOV & MIKHAILOV, 1966): lower Volgian, (SOKOLOV, 1901, "Wetlianian" horizon), middle Volgian (NIKITIN, 1881 a, "lower Volgian stage"), and upper Volgian (NIKITIN, 1881 b, "upper Volgian stage").

Traditionally, the Volgian crowned the Jurassic system and was considered to an equivalent of the Tithonian stage. However, many data, in several areas of the world, contradict the correlation adopted in Russia (SEY & KALACHEVA, 1993). A recent resolution of standing commission of the Interdepartmental Stratigraphic Committee of Russia (ISC) on the Jurassic and Cretaceous systems (1996, unpublished) proposed to draw the Jurassic/Cretaceous boundary in the Boreal realm between the middle and upper substage of the Volgian (Nikitini/Fulgens Zones). In that way, the upper Volgian is correlated with two lower zones of the Berriasian stage. In the subboreal province, such a break corresponds to the boundary between marine series with ammonites of the Dorset Portland Beds and lagoonal-lacustrine facies of the Purbeck Beds. The top of Portlandian *sensu anglico* is putting above the Oppressus Zone (BIRKELUND, *et al.*, 1984) and the Portlandian last zones (Primitivus, Preplicomphalus and Lamplughi Zones) can be an equivalent to the upper Volgian.

At the All-Russian Conference in Saint Petersbourg in 1988 (Resolution, 1993), on the development of an unified stratigraphic scheme of the Mesozoic deposits of the Russian Platform, the Volgian stage was subdivided into the following substages, zones and subzones: lower substage (Klimovi Zone, Sokolovi Zone, Pseudoscythica Zone), middle substage (Panderi Zone with Pavlovi and Zarajskensis Subzones, Virgatus Zone with Gerassimovi, Virgatus and Rosanovi Subzones, Nikitini Zone with Blakei and Nikitini Subzones, Oppressus Zone), and upper substage (Fulgens Zone, Subditus Zone, Nodiger Zone with Mosquensis and Nodiger Subzones).

Today Volgian is differently subdivided (MESEZHNIKOV, 1982; MITTA, 1993 ; GERASIMOV *et al.*, 1995):

— Klimovi Zone MICHAILOV (1962 a): *Ilowaiskya klimovi* Ilovaisky, *Neochetoceras* aff. *steraspis* (Opp.), *Glochiceras* sp., *Gravesia* cf. *gigas* (d'Orb.), *Sutneria* aff. *subeumela* (Schneid).

— Sokolovi Zone ILOVAISKY & FLORENSKY (1941): *Ilowaiskya sokolovi* Ilovaisky, *I. pavida* Ilovaisky, *Haploceras* aff. *elimatum* (Opp.), *Glochiceras* aff. *lithographicum* (Opp.), *Glochiceras* aff. *parcevali* (Font.).

— Pseudoscythica Zone ILOVAISKY & FLORENSKY (1941): *Ilowaiskya schaschkovae* Ilovaisky, *I. pseudoscythica* Ilovaisky, *Pectinatites* aff. *pectinatus* (Phillips), *P. ianschini* (Ilovaisky), *P. tenuicostatus* Mikhailov, *Weatleyites* aff. *aestlecottensis* (Salfeld), *W. arkelli* Michailov, *W. spathi* Mikhailov, *Physodoceras neuburgense* (Oppel).

— Panderi Zone ROZANOV (1906): *Zaraiskites zarajskensis* (Michalski), *Z. scythicus* (Vischniakoff), *Z. michalskii* Mitta, *Z. quenstedti* (Rouillier & Fahrenkohl), *Z. tschernyschovi* (Michalski), *Acuticostites acuticostatus* (Michalski), *A. bitrifurcatus* Mitta, *Dorsoplanites dorsoplanus* (Vischniakoff), *Dorsoplanites panderi* (d'Orbigny), *Pavlovia pavlovi* (Michalski).

Subdivision of Panderi Zone into two Subzones is impossible. The same ammonite species occur in lower and upper parts of zone; there are not biostratigraphicaly or lithostratigraphicaly limited. MIKHAILOV (1962 a) who proposed the subdivision of the Panderi Zone into two subzones, as ILOVAISKY (ILOVAISKY & FLORENSKY, 1941) which proposed such subdivision, have based his suppositions on Rozanov's indications. He was the first, who believed in the compound composition Panderi Zone. However, ILOVAISKY & MIKHAILOV did not take into account that the greater part of Rozanov's "lower Subzone Panderi-Zone" was included by the latest workers into the lower Volgian "Wetlianian horizon".

Virgatus Zone ROUILLIER (1845) (emend. by LAHUSEN, 1883 and ROSANOV, 1906): *Virgatites virgatus* (Buch), *V. sosia* (Vischniakoff), *V. pusillus* (Michalski), *V. pallasianus* (d'Orb.), *V. larisae*

Mitta, *V. gerassimovi* Mitta, *V. rosanovi* Michailov, *V. crassicostatus* Mitta, *Dorsoplanites serus* Gerasimov, *D. rosanovi* Gerasimov, *Serbarinovella serbarinovi* Mitta, *S. ringsteadiaeformis* (Gerasimov), *Lomonossovella lomonossovi* (Vischniakoff), *Craspedites ivanovi* Gerasimov, *C. pseudofragilis* Gerasimov, *Acuticostites acuticostatus* (Michalski), *Laugeites stschurowskii* (Nikitin), *Crendonites kuncevi* Michailov.

The subdivision of the Virgatus Zone is based on the species and succession of the genus *Virgatites* and *Dorsoplanites:*

— Gerassimovi Subzone ROZANOV (1919) *Virgatites gerassimovi* Mitta, *V. pusillus* (Michalski), *V. pallasianus* (d'Orb.), *V. sosia* (Vischniakoff), *Dorsoplanites serus* Gerasimov, *D. rosanovi* Gerasimov, *Lomonossovella lomonossovi* (Vischniakoff), *Acuticostites acuticostatus* (Michalski).

— Virgatus Subzone ROUILLIER (1845) (emend. by ROSANOV, 1919): *Virgatites virgatus* (Buch), *V. pallasianus* (d'Orbigny), *V. sosia* Vischniakoff, *V. larisae* Mitta, *V. crassicostatus* Mitta., *Dorsoplanites serus* Gerasimov, *D. rosanovi* Gerasimov, *Lomonossovella lomonossovi* (Vischniakoff), *Serbarinovella serbarinovi* Mitta, *S. ringsteadiaeformis* (Gerasimov), *Craspedites ivanovi* Gerasimov, *C. pseudofragilis* Gerasimov.

— Rosanovi Subzone ROZANOV (1913) (= Ivanovi Subzone): *Virgatites virgatus* (Buch), *V. rosanovi* Michailov, *V. pallasianus* (d'Orbigny), *V. sosia* (Vischniakoff), *Dorsoplanites serus* Gerasimov, *D. rosanovi* Gerasimov, *Lomonossovella lomonossovi* (Vischniakoff), *Craspedites ivanovi* Gerasimov, *C. pseudofragilis* Gerasimov, *Crendonites kuncevi* Michailov, *Laugeites stschurowskii* (Nikitin).

— Nikitini Zone LAHUSEN (1883): *Epivirgatites nikitini* (Michalski), *E. bipliciformis* (Nikitin), *E. lahuseni* (Nikitin) *Laugeites stschurowskii* (Nikitin), *L. aenivanovi* Mitta, *Lomonossovella lomonossovi* (Vischniakoff), *Craspedites ivanovi* Gerasimov, *Craspedites pseudofragilis* Gerasimov.

The separation of the upper part of formerly Nikitini Zone as Oppressus Zone by CASEY & MESEZHNIKOV (1986) cannot be adopted. Nikitini Zone is the interval of distribution of *Epivirgatites nikitini* (Michalski), which is found in complete section of zone in its formerly volume. The separation of "the beds with *Paracraspedites oppressus*", as upper subzone of Nikitini Zone, is also impossible. The presence of the western-european genus *Paracraspedites* is not confirmed in middle Volgian.

The separation of the lower part Nikitini Zone into Blakei Subzone cannot be also adopted. The name *Lomonossovella blakei* (Pavlow) *emend.* MIKHAILOV is the younger synonym of *L. lomonossovi* (Vischniakoff). There are no data which allow to distinguish the complexes of "Blakei and Nikitini Subzones". The differences shown by CASEY & MESEZHNIKOV (1986) had geographical nature. They cannot be adopted as evidence of more older Nikitini Zone age in near-Moscow and upper Volga than the age of the beds in middle Volgian.

Fulgens Zone NIKITIN (1888): *Craspedites fragilis* (Trautschold), *C. okensis* (d'Orb.), *C. nekrassovi* Prigorovsky, *C. krilovi* Prigorovsky, *C. subditoides* (Nikitin), *Garniericeras catenulatum* (Fischer), *G. interjectum* (Nikitin), *Kachpurites fulgens* (Trautschold), *K. subfulgens* (Nikitin).

Subditus Zone NIKITIN (1888): *Craspedites okensis* (d'Orb.), *C. nekrassovi* Prigorovsky, *C. jugensis* Prigorovsky, *C. subditus* (Trautschold), *C. subditoides* (Nikitin), *Garniericeras catenulatum* (Fischer), *G. interjectum* (Nikitin).

Nodiger Zone NIKITIN (1888): *Craspedites nodiger* (Eichwald), *C. triptychus* (Nikitin), *C. kaschpuricus* (Trautschold), *C. parakaschpuricus* Gerasimov, *C. milkovensis* Strmooukhov, *C. kuznetzovi* (Sokolov), *C. mosquensis* Gerasimov, *Garniericeras subclypeiforme* (Milaschevitsch).

The Nodiger Zone admits two subdivisions: Subzone of *Craspedites mosquensis* (lower) and Subzone of *Craspedites nodiger* (upper). These subzones differ by the distribution of species *Craspedites mosquensis* Gerasimov and *C. triptychus* (Nikitin) in the lower part (subzone) of Nodiger Zone.

The correlations of the base of the lower Volgian with the Kimmeridgian/Tithonian boundary of western-Europe area could be assured, on the basis of genus *Gravesia* found in the Klimovi Zone on the Gorodische lectostratotypical section (MESEZHNIKOV, 1988). On a same way, *Neochetoceras* and *Glochiceras,* mentioned by GERASIMOV & MIKHAILOV (1966), could be a possible equivalent with the lowermost Tithonian (Hybonotum Zone).

The correlation of the base of the middle Volgian (Panderi Zone) is much less certain. The pavlovids of the Panderi Zone, suggest a rough parallel with the Pallasioides/Rotunda boundary in Britain (CALLOMON & BIRKELUND, 1982).

Higher in the succession, the group of *Epivirgatites nikitini* (MICHALSKI, 1890), has been equated with the Albani-Glaucolithus Zones of the English Portlandian (WIMBLEDON & COPE, 1978). "*Lomonossovella*" *lomonossovi* (Vishniakov, 1882) appears to be a true *Kerberites* Buckmann from the Kerberus Zone (CALLOMON & BIRKELUND, 1982). The upper Volgian begins everywhere with the appearance of *Craspedites*. The closest correspondence which can suggest is between the Nodiger Zone and the English Preplicomphalus Zone, in which the *Craspedites* has also been found (CASEY, 1973, CALLOMON & BIRKELUND, 1982).

STRATIGRAPHICAL DISTRIBUTION OF RUSSIAN PLATFORM "OIL SHALE BANDS" AND THEIR GEOCHEMICAL TRENDS

The background facies of the Upper Jurassic deposits from the Russian Platform are mainly mudstone and marlstone with $CaCO_3$ content lower than 40% (25% in average). Carbonate-free sandstone and siltstone, as subordinate facies, are mainly related to upper Volgian deposits. Some samples show higher carbonate content (50-80%), and correspond either to sandstone with calcitic cement or carbonate-nodules within the mudstone. The background facies show a very variable Corg. content, from about 1 wt% (higher than the average for shales) to very high values (10 wt%), that are elevated compared to recent and ancient marine sediments. Some levels show higher Corg. (up to 50%) and correspond to finely laminated shales, here called oil shales (Fig. 6). Such a richness is exceptional and the corresponding sediment could be regarded as pure organic matter.

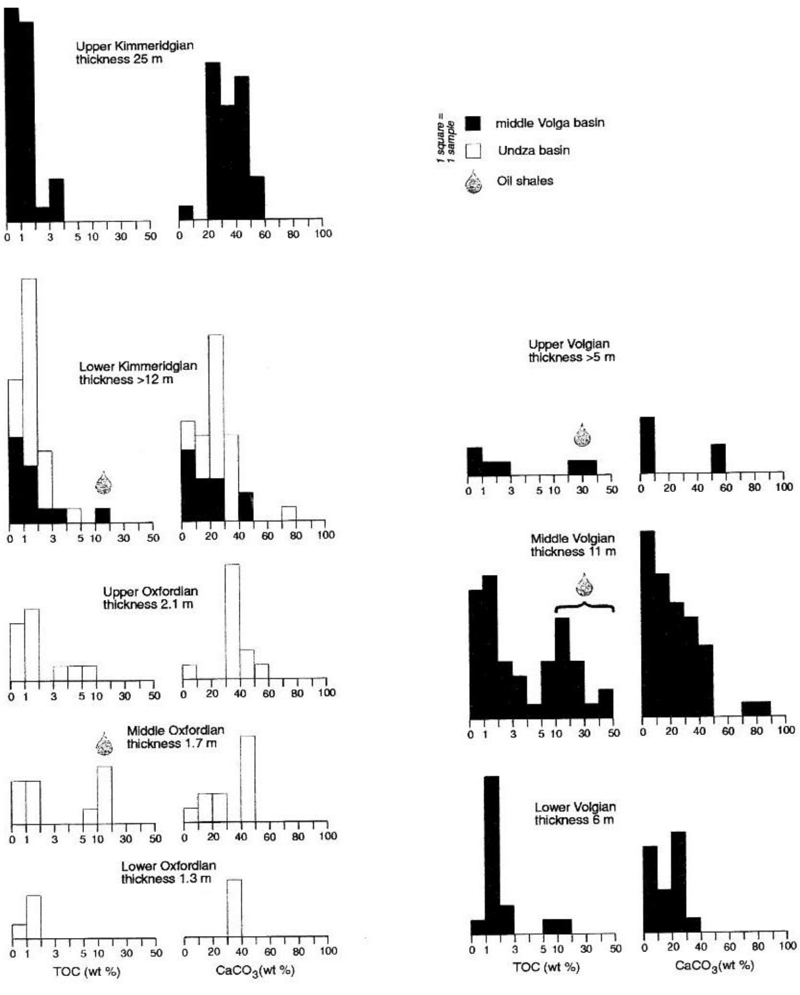

FIG. 6.— Frequency distribution for TOC and $CaCO_3$ content of samples from the Upper Jurassic of the Russian Platform. Samples with larges wood fragments are here disregarded (Note change in TOC scale axis for values above 5 and 10 % TOC).

FIG. 6.— Histogrammes des fréquences du contenu en COT et $CaCO_3$ des échantillons du Jurassique supérieur de la plate-forme russe. Les échantillons contenant de grands fragments de bois sont ici négligés. (Noter le changement d'échelle des abscisses pour les valeurs au dessus de 5 et 10% de COT).

The pyrolytic measurements show that the organic matter is widely distributed between type II (marine) and type IV (altered organic matter), according to the broad distribution of hydrogen index (HI) values, ranging from 10 to 700 mg HC/g TOC (Fig. 7). Oil shales show the higher HI values and are related to type II organic matter. Nevertheless, such facies may likewise contain organic matter with HI values less than 150. Most of the mudstone and marlstone show likewise low to medium HI values (23 to 250). These low values, associated with low organic carbon content, support the hypothesis of strong alteration of the organic matter. HI-values in organic-lean sediments, however, can be due to mineral matrix effect, e.g. adsorption of pyrolytically generated hydrocarbons on clay mineral surfaces (ESPITALIÉ *et al.*, 1985-86). Detailed organic geochemical studies are in progress in order to carefully determined the type of organic matter and to characterized the depositional environment by the mean of biomarkers.

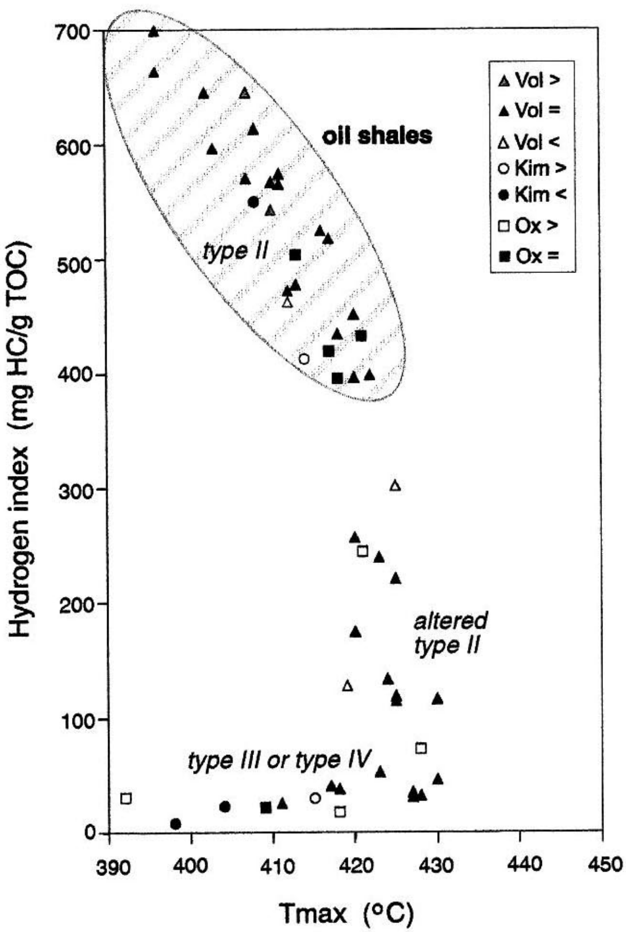

FIG. 7.— Hydrogen index vs Tmax diagram of selected samples from the Upper Jurassic of the Russian Platform.

FIG. 7.— Diagramme Index d'hydrogène vs. Tmax d'échantillons sélectionnés dans le Jurassique supérieur de la plate-forme russe.

Petroleum potentials of the oil shales are very good with an average of 95 kg HC/t of rock and some exceptional potentials ranging from 200 to 300 kg/t for the Volgian oil shale bands.

The oil shales show a variable frequency through the studied interval and are mostly concentrated in six bands, separated by the background mudstone and marlstone with less Corg. content. They are by stratigraphic order (Fig. 8):

— a 12 cm-thick band, occurring close to the middle-upper Oxfordian boundary (Glosense Zone) in the Makariev section (level Mk 14). Its organic content varies from 11 to 19% TOC. This level is overlain by 15 cm of dark claystones with bioturbations (level Mk 13), containing up to 6.5% TOC. A discontinuous, cm-thick oil shale level exists locally below this first horizon. This first oil shale band is well known in subsurface as far as Moscow, where its thickness increases up to 1 m, whereas its organic richness is decreasing (only 3% Corg, according to authors unpublished measurements);

— a lower Kimmeridgian (Cymodoce Zone) oil shale band is described here for the first time in the Russian Platform. This level is 50 cm thick in the Mimei village section (level Ta 5) and its organic richness is 15% TOC;

— *the most famous and widespread oil shale band is of middle Volgian age and is more precisely* related to the Panderi Zone. This band was investigated in detail along the 6 m-thick profile of Gorodische (level Go 11). It is made by alternation of black shales and dark claystones. The organic richness of black shales varies from 2.3 to 44.5% TOC with a 16.5% mean value. The dark claystones contain between 0.5 and 5.4% TOC;

— the next band belongs to the same Substage but has a Virgatus Zone dating. This level was not recognised along the Gorodische section because of the predominance of sandy facies;

— the fifth band, from the base of upper Volgian (Fulgens Zone), was not recognised along the Gorodishche or Kashpir sections because of the predominance of sandy and calcareous-sandy facies;

— the last band belongs to the uppermost Volgian (Nodiger Zone), equivalent to the lower Berriasian. This level has a thickness ranging between 6 to 15 cm in the Kasphir section (level Ka 20) and an organic richness fluctuating from 22 to 33% TOC.

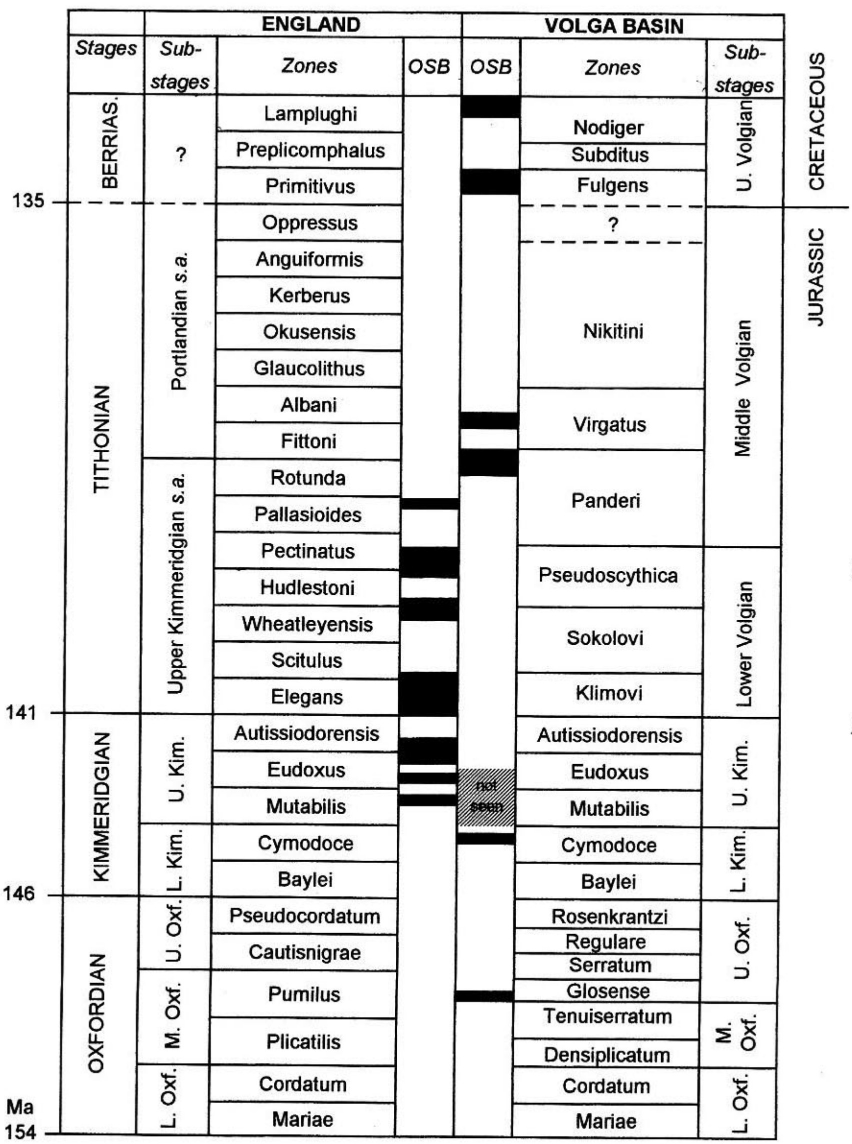

FIG. 8.— Stratigraphical distribution of the oil shale band (OSB) in both England and Volga basins. Time scale according to ODIN & ODIN (1990). See text for explanation.

FIG. 8.— Distribution temporelle des bandes de schistes bitumineux (OSB) en Angleterre et dans le bassin de la Volga. Échelle des temps d'après ODIN & ODIN (1990). Voir le texte pour les explications.

It should be noted that the upper Kimmeridgian deposits were not completely investigated during our field work and the Mutabilis Zone and basal part of the Eudoxus Zone was not recognised.

COMPARISON WITH THE KIMMERIDGE CLAY FORMATION

Late Jurassic is known to have been prone to the deposition of Corg.-rich series at a global scale and especially in the boreal domain (NORTH, 1979; ULMISHEK & KLEMME, 1990; BAUDIN, 1995). The Kimmeridge Clay Formation is one of the famous petroleum source rock which was deposited during this time interval. It extends onshore from the Wessex basin in southern England to the Cleveland basin of northern Yorkshire and is the main source rock in the North Sea basin. It has an homogeneous dark-coloured mudstone facies with a few, apparently isochronous, carbonate and oil-shale marker-beds that can be correlated all over the basin (COX & GALLOIS, 1981).

Because the age of the Kimmeridge Clay Formation ranges from Kimmeridgian to Volgian, that includes a large part of the studied interval on the Volga basin, we attempt to compare the stratigraphic distribution of oil shales between these two provinces.

According to the works of GALLOIS (1978), COX & GALLOIS (1981), WIGNALL (1991), HERBIN *et al.* (1991), HERBIN & GEYSSANT (1993) and RAMDANI (1996) five oil shale bands can be recognized in the Kimmeridge Clay Formation (Fig. 8):

— a middle Eudoxus band (BGS bed 29 *sensu* GALLOIS, 1979);

— an upper Eudoxus-lower Autissiodorensis band (BGS beds 32 and 33);

— an Elegans-basal Scitulus band (BGS beds 36 and 37);

— an upper Wheatleyensis-basal Hudlestoni band (BGS beds 42 and 43);

— an uppermost Hudlestoni-Pectinatus band (beds 45-47 *sensu* WIGNALL, 1991);

Although the frequency of oil shale bands is greater in the middle part of the Formation (Eudoxus to Pectinatus Zones), some oil shales are present in the Mutabilis and Pallasioides Zones (Fig. 8). The Mutabilis oil shale band is demonstrated by HERBIN *et al.* (1991) in the Yorkshire, whereas the Pallasioides band corresponds in the Dorset to beds 52-54 (Wignall, 1991).

It appears that the stratigraphic distribution of the oil shale bands from the Kimmeridge Clay Formation is completely different from those of the Volga basin (Fig. 8). As might be expected, the probably shallower environment in the Volga basin did not allow the preservation of organic matter during these time intervals. It appears that either these intervals were not associated with a relative change in water depth sufficient to allow dysoxic-anoxic conditions to be established or that other watermass factors were not suitable to organic matter preservation during the upper Kimmeridgian and lower Volgian. On the contrary, oil shale bands are present on the Russian Platform during upper Oxfordian, lower Kimmeridgian, middle and upper Volgian when the environments were more sandy and shallower in England and unfavourable to the organic matter preservation.

This lack of temporal correlation of the organic-rich deposits at a large scale during the Upper Jurassic has been mentioned previously for the Tethyan realm (BAUDIN, 1995). It seems that the Upper Jurassic was a suitable period for organic matter preservation, but any stratigraphic interval can be regarded as global time-slice prolific for source rock deposition. The oil shale bands discussed here are definitely not equivalent to oceanic anoxic events as the lower Toarcian (JENKYNS, 1988) or Cenomanian-Turonian (BUSSON & CORNÉE, 1996) events.

CONCLUSION

The above biostratigraphic study of the Upper Jurassic from middle Volgian basin has enabled the Russian series to be correlated more precisely with the western-european standard zonation. Concerning the Oxfordian Stage, the use of Cardioceratids faunas authorised some equivalencies with boreal and sub-boreal successions. The Oxfordian/Kimmeridgian boundary is precisely identified with the basal Kimmeridgian Densicostata Horizon.

The best biostratigraphical correlations between the Russian Platform and western Europe are achieved for the Kimmeridgian stage. Seven ammonites horizons are common within these two areas: *P. densicostata, P. baylei, O. lallierianum, A. caletanum, A. contejeani, A. yo and A. autissiodorensis.* Morever, the levels with *R. uralensis* can be probably subdivided with various *Rasenia* species. Similarly, the "Acanthicum Zone *auct*" seats many suboreal Aulacostephanids and a more precise biostratigraphical scheme can be obtain with better correlations between Russian Platform and the subboreal province (North Sea basin, southern England, Aquitaine and Paris basins, northern Germany...).

On the other hand, the equivalences between the regional "Volgian stage" and/or Tithonian/Portlandian *sensu anglico*, are much less certain. Some difficulties proceeded of a pronounced faunal provincialism. Correspondences can be only suggested by affinities of the endemic Russian ammonites and the boreal faunas. Local scheme is still necessary.

Geochemical characterisation of the Upper Jurassic series from the Russian Platform show several intervals with high organic content (Corg >10%) and good petroleum potentials. Nevertheless, they are not synchronous with organic-rich intervals from the Kimmeridge Clay Formation. Further studies are needed to understand the depositional control of these oil shales at a small scale, but the present data clearly indicate that oil shale bands cannot be taken as marker beds at a large scale.

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