CONDITIONS OF FORMATION AND OIL-GAS POTENTIAL OF PERMIAN AND TRIASSIC DEPOSITS IN THE NORTHERN TIMAN-PECHORA BASIN

A. V. Stupakova, Geology Department, Moscow State University, Moscow

ABSTRACT

The depositional history and oil-gas potential of the northern part of the Timan-Pechora basin, the region with best prospects for hydrocarbons within the Permo-Triassic terrigenous complex of the basin, are related to the adjacent marine South Barents depression. Permo-Triassic sediments are divided into marine and continental formations which occupy the northern part of the basin and continue, with a more complete section, to the South Barents depression, where they form distinct oil- and gas-bearing units.

Paleogeographic and paleotectonic reconstruction of the depositional conditions of the Permo-Triassic, based on the results of well logging, the cyclic structure and nature of the lithologic units, and their spatial relationships, permits the identification of facies complexes and their distribution within each formation. The marine facies correspond to distal portions of a shelf, open to the shallow-sea environment, and to onshore and offshore sedimentary accumulations of Permian age. The continental facies include onshore plains, alluvial and lacustrine plains, and meandering and multi-channel river deposits of Triassic age.

The facies of the Permo-Triassic deposits determine the location of zones of oil and gas accumulation. These zones are related to areas of shallow-water sand bodies, sub-sea levees, offshore bars parallel to the coast, and deltaic and alluvial deposits.

The distribution of these facies, and the corresponding Permo-Triassic reservoir rocks of the northern Timan-Pechora basin, was primarily influenced by the developing Barents Sea depression. Intensive subsidence of the South Barents depression started in Artinskian to Kungurian (mid-Permian) time, resulting in a sub-meridional zonation along the structure of the basement. These large, first-order tectonic elements were later overprinted by a sub-latitudinal facies zonation which became most distinct at the end of the Permian. By the end of the Permian, a relatively stable sub-latitudinal zonation had formed, restricting the influence of the Barents Sea depression on the territory of the basin. This zone later provided a lateral migration path for hydrocarbons from the north along the Permo-Triassic deposits.

The analysis of the distribution of reservoir rocks, formed of sand bodies of varying origins, and possible hydrocarbon migration paths, permits the identification of the best areas for detailed seismic exploration and deep prospect drilling.

INTRODUCTION

The northern portion of the Timan-Pechora basin is part of the continent to ocean transition zone in the Western Arctic (Fig.1; Dedeev and Zaporozhtseva, 1985). This is indicated by the close association between the internal structure and conditions of formation of the northern continental margin of this basin and the adjacent water-covered area of the South Barents depression. This relationship has been indirectly observed for almost all sequences in the sedimentary cover. It is particularly strong in the Permian and Triassic sediments, because their time of formation corresponded to that of the active development of the South Barents depression.

To understand the influence of the depression on the northern Timan-Pechora basin during Permian and Triassic times, the processes of formation of the deposits of corresponding age in the depression and the basin were analyzed. Two successions were examined, the regressive marine Permian and continental Triassic (Fig.2). For each succession, the types of stratigraphic sequences were analyzed (as characterized by specific cyclicity and bedding forms) and their distributions were studied.

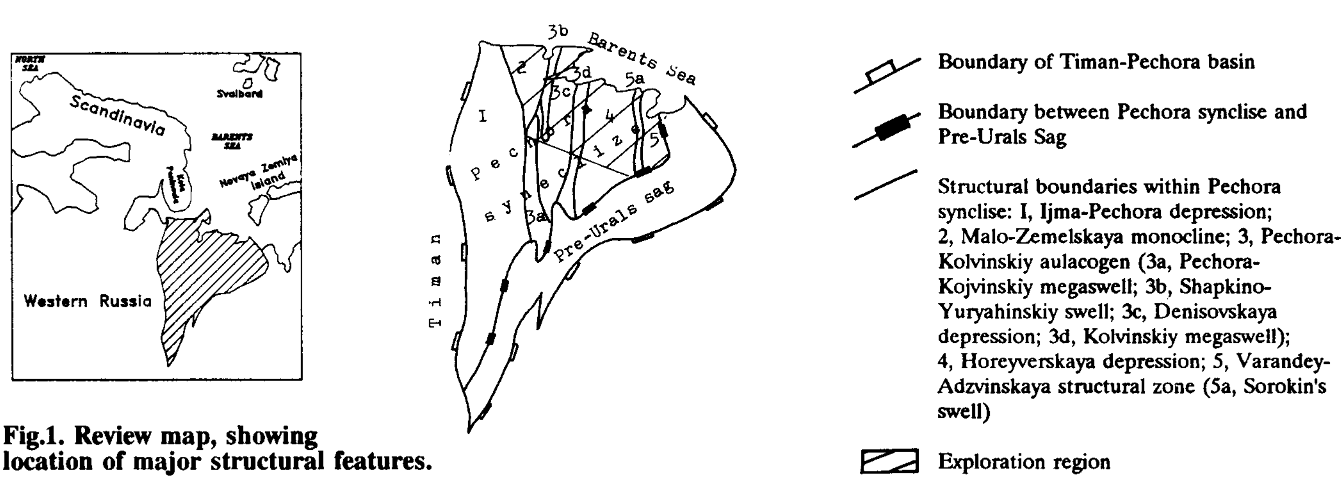


Fig.1. Review map, showing location of major structural features.

These sequences form geological bodies, comparable in size and age, which represent specific paleogeographic sedimentary environments; in other words, they are considered to be facies.

Paleogeographic reconstruction of Permian-Triassic depositional environments was conducted using the methods of King (1972), Reineck and Singh (1973), Busch (1974), Conybeare (1976), Allen (1982), Coleman (1982), Selley (1976, 1978), Reading (1986), and others, based on the results of well logs, the cyclic nature and lithologic composition, and spatial relationships, which permit us to distinguish facies and their distribution within each succession.

FACIES, PALEOGEOGRAPHY, AND PALEOSTRUCTURE

The Permian regressive succession marks the change from a shallow-water and marine regime of sediment accumulation to nearshore and onshore conditions. Its lower boundary is the contact with sediment accumulated during the Late Sakmarian to Early Artinskian stages (Early Permian). From this surface, carbonate material was gradually replaced upward in section by terrigenous sediment. The upper boundary of the regressive succession is the stratigraphic break at the base of the Triassic system.

The Triassic continental succession includes onshore plain facies, lacustrine facies, and alluvial facies of meandering and braided streams. It is bounded by two stratigraphic breaks--at the bases of the Triassic and the Jurassic systems.

In the Permian succession, marine facies dominated. During Artinskian time, a shallow-water and marine regime, accompanied by carbonate sedimentation, occupied most of the Pechora syncline (Fig.3). The South Barents depression and distal shelf environments existed only in the northern part of this region, where the corresponding facies are represented by mudstones, siltstones, and clastic carbonate sand and silt (Fig.4).

The distribution of facies reveals not only the paleogeographic situation, but also the paleostructure of this territory during various time intervals.

In Artinskian time (late Early Permian), the structural plan of the Pechora syncline was the same as in the present. The most distinct feature is the Kolva megaswell, which separated the Pechora syncline into two large zones, the western and eastern, and blocked the free influx of clastic material from one zone to the other. The main source region was Scandinavia. A significant part of the terrigenous sediment was concentrated in the northern, marine portion of the modern Timan-Pechora basin. Terrigenous material entered the Pechora syncline only along the shelf zones

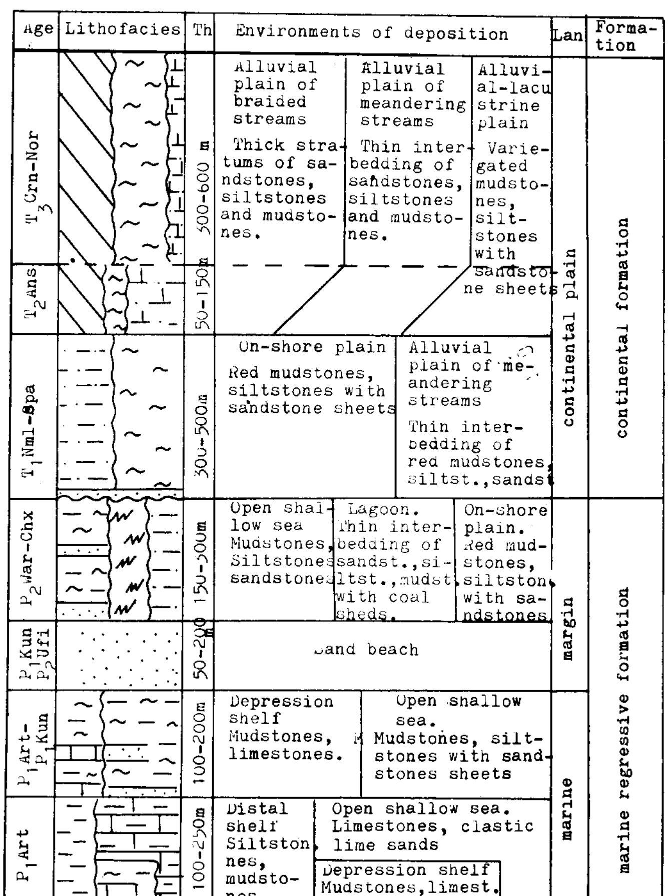
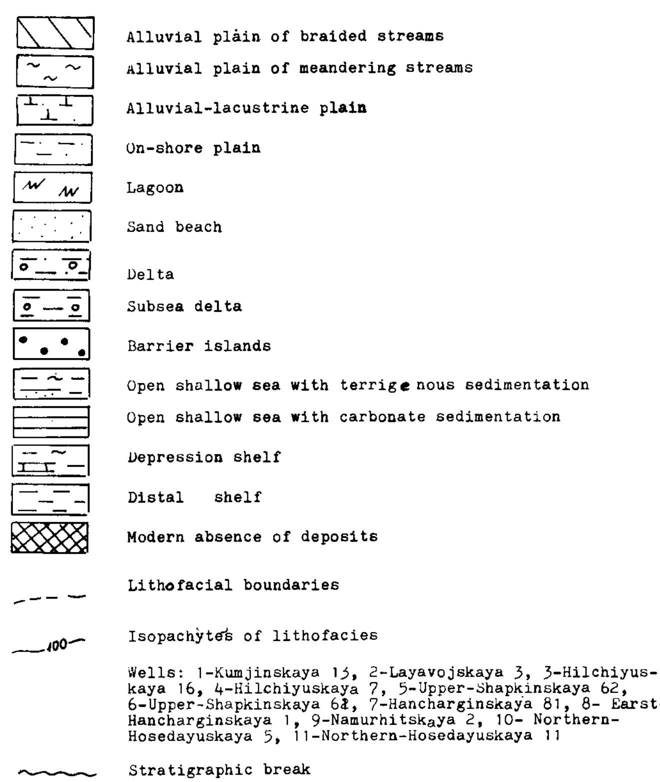


Fig.2. Formation scheme of Permian and Triassic deposits in the northern Timan-Pechora basin.



Legend for lithofacies maps and paleogeological sections

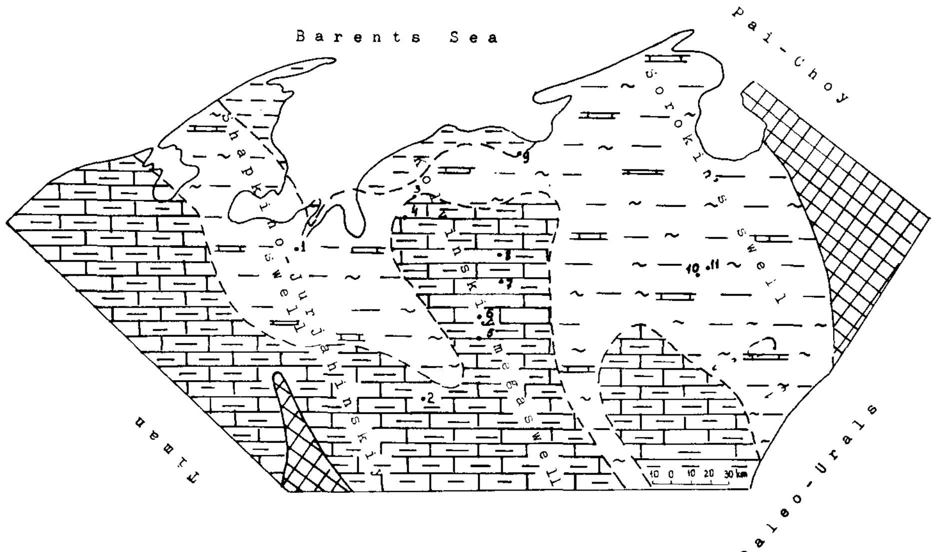


Fig.3. Lithofacies in early Artinskian time.

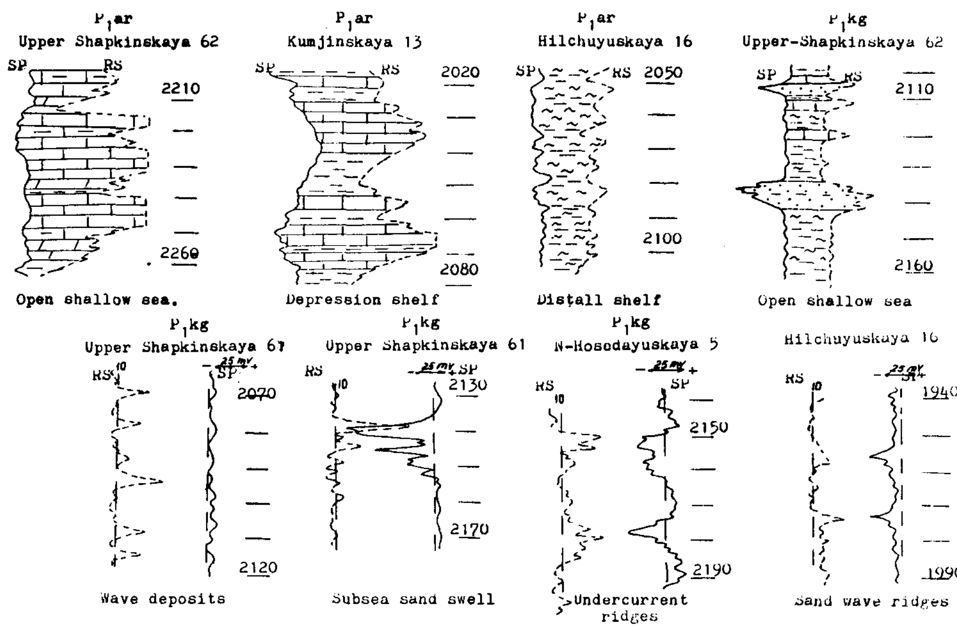


Fig.4. Type of sections and well log models for marine facies. (See Fig.2 for age abbreviations; see legend and lithofacies maps for well numbers and locations.)

of the South Barents depression. The influence of the Barents Sea depression can be observed only in the northernmost part of the study area.

During Kungurian time (early Late Permian), facies distributions reflect regional changes within the whole basin. The broad, carbonate, open, shallow-marine facies were reduced by a considerable extent. These facies were replaced by mudstones and siltstones, with some sandstone interbeds, which formed under open, shallow-sea conditions accompanied by terrigenous sedimentation.

Terrigenous material was transported into this region from the Paleo-Urals, which became the main sediment source. The southern part of the territory developed under the direct influence of the Pre-Urals marginal depression, whereas the northern part was involved in the more intensive subsidence of the South Barents depression. At this time, a sub-latitudinal facies zonation was superimposed on sub-meridional structures.

In the Late Permian, during the final stage of regression, a short transgression occurred. As a result,

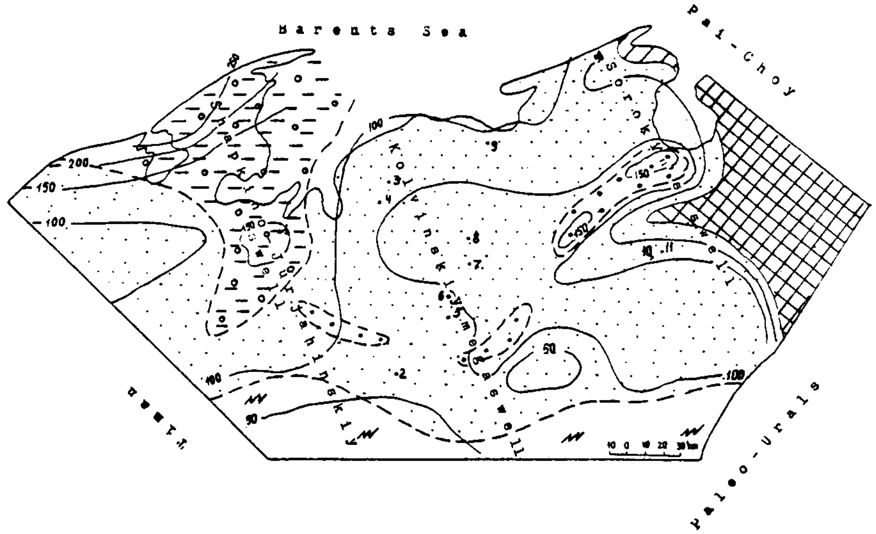


Fig.5. Lithofacies in late Kungurian-early Ufimian time.

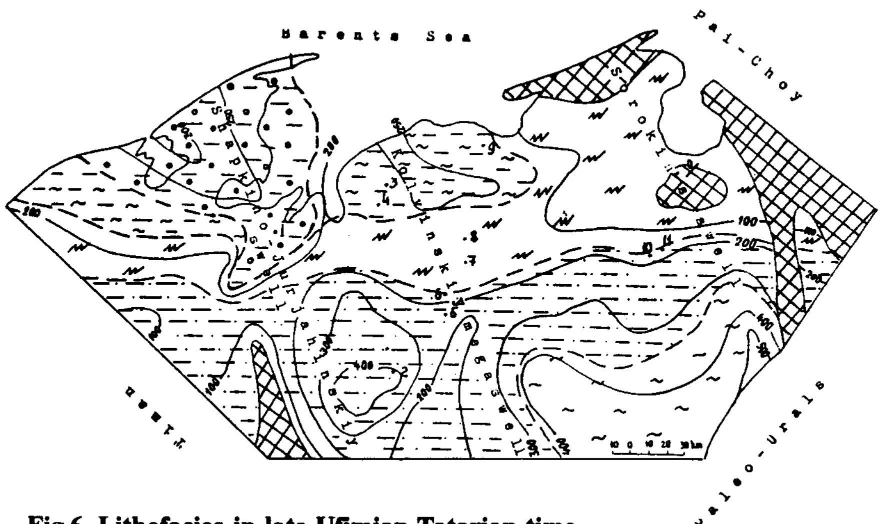


Fig.6. Lithofacies in late Ufimian-Tatarian time.

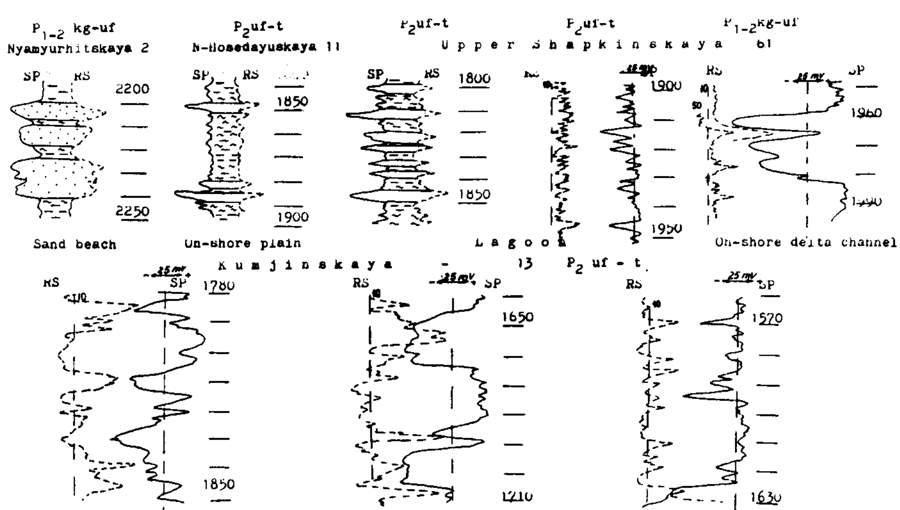


Fig.7. Type of sections and well log models for marginal facies.

regional sandy nearshore facies (Fig.5) were replaced by silty and clayey facies of the onshore plain in the southern part of the study area, by coal-bearing facies of offshore lagoons and swamps in the central part, and by clayey shallow-water marine facies in the north (Figs.6 and 7).

At that time, sub-latitudinal zonation was the most distinct, and a relatively stable central zone can be mapped which separates the regions of influence of the Pre-Urals marginal trough and the Barents Sea depression. The stability of this zone is indicated by offshore lagoonal facies with the accumulation of coal, and by the location of the minimum in sedimentary thickness, which increases both to the south and to the north of the zone.

Sub-latitudinal zonation and Late Permian facies boundaries persisted into Early Triassic time. However, Late Permian open, shallow-marine facies were replaced by Early Triassic onshore plain facies (Fig.8), which are represented by red mudstones, siltstones, with some sandstone interbeds of onshore alluvial plain and deltaic deposits (Fig.9). A deltaic plain occupied the western part of the study area and was the result of preexisting features. The channel was directed to the northwest. The Paleo-Urals and the Timan region served as the source for sediments.

During the Middle Triassic, the development of the Pre-Urals marginal trough terminated, and the expansion of the South Barents depression placed the study area into active subsidence. There was some tectonic activity in the region and the formation of the Pai-Khoi-Novaya Zemlya fold belt caused changes in facies zonation from sub-latitudinal to sub-meridional. The Pai-Khoi-Novaya Zemlya fold belt became the new predominant sediment source (Milanovsky, 1987). As a result, braided-stream facies began to develop in the territory adjacent to the Pai-Khoi. In the west, they are replaced by lacustrine facies and alluvial facies of meandering streams. Deltaic facies were reduced and occupied only the far northern part of the region (Fig.10).

By Late Triassic time, the general uplift of this territory resulted in the expansion of braided-stream facies in the eastern half of the Pechora syncline and the reduction of lacustrine facies (Fig.11). Lacustrine plain facies were replaced by alluvial facies of meandering streams. The northern Timan-Pechora basin acquired a structure similar to that of the present.

Thus, in the Permian and Triassic of the northern part of the Pechora syncline, we observe the constant interaction of two large geotectonic elements, the Paleo-Urals and the South Barents depression. Their interaction is the cause for the sub-latitudinal facial zonation of Permian and Triassic deposits. However, it is interesting to note that the boundaries of those sub-latitudinal facial zones had relatively fixed positions at different times and are commonly located along the same structures.

HYDROCARBON POTENTIAL

A corresponding zonation is present in the distribution of hydrocarbons as well. Hydrocarbons from the Permian to Triassic complex are not genetically homogeneous between the deposits of the northern and more southerly regions. The generation and accumulation of hydrocarbons are different in these areas. The separation of these areas and their sub-latitudinal boundaries frequently can be outlined within deeper horizons by seismic investigations and is, probably, the most important reason for the differences. The relatively stable zone can be interpreted as a paleoflexural uplift which existed throughout the history of the basin. In Late Permian and Early Triassic times, this zone separated the influence of the Pre-Urals trough and the Southern Barents Sea depression (Fig.12).

The relatively stable sub-latitudinal zone also separated areas with different conditions of

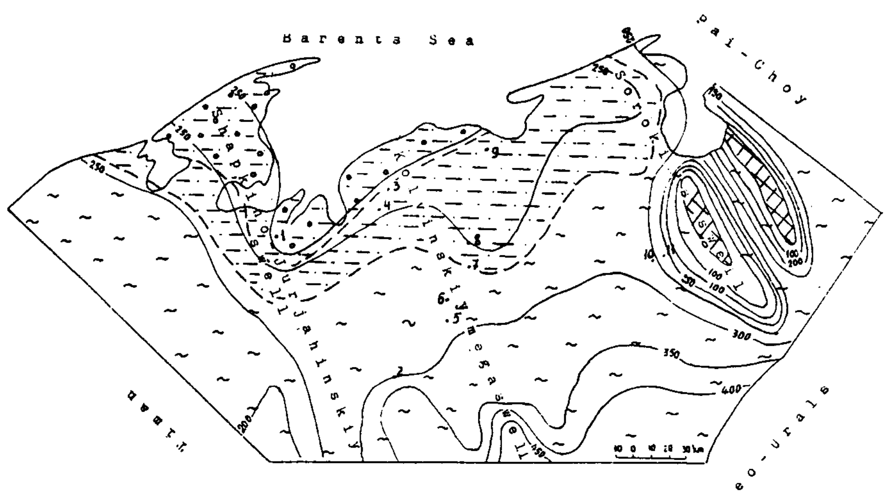


Fig.8. Lithofacies in Early Triassic time.

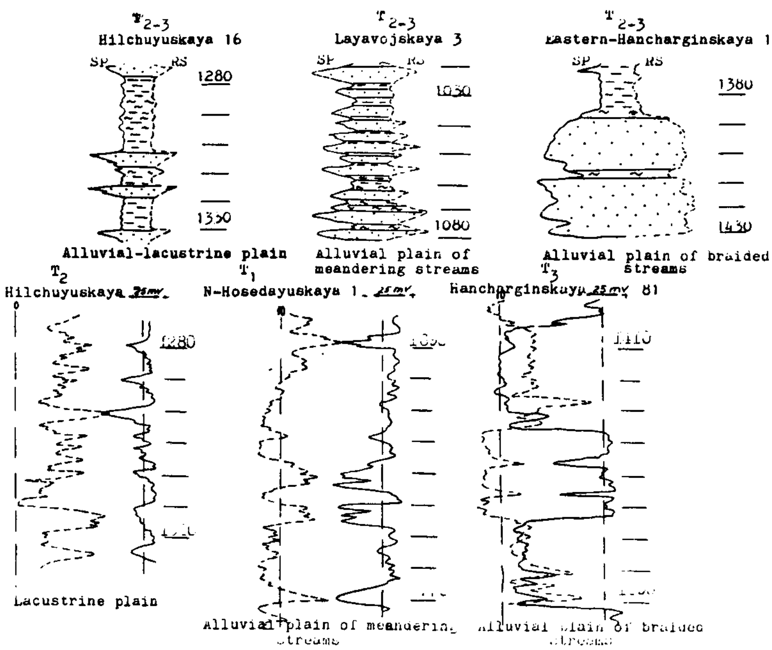


Fig.9. Type of sections and well log models for continental facies.

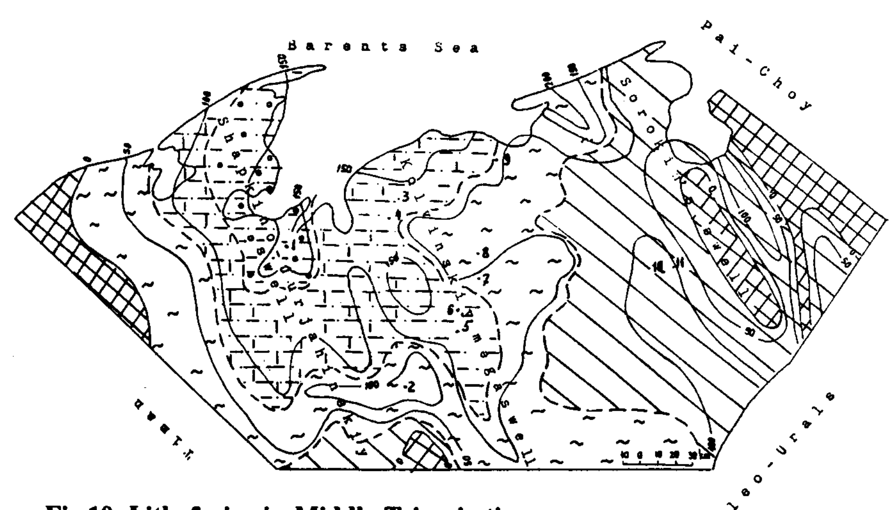


Fig.10. Lithofacies in Middle Triassic time.

hydrocarbon accumulation. The deposits within this zone have poor permeability. As a result, to the north of the zone, hydrocarbon accumulations were formed by migration from the Barents Sea depression. As the great flow of hydrocarbons from the north approached the different paleostructural and paleofacial environments with poor permeability of the latitudinal zone, it began to disperse. Therefore, within this zone we can observe many hydrocarbon shows in the Permian and Triassic sediments but no deposits.

In the more southern region, hydrocarbon influx into the Permian and Triassic sediments was possible only along tectonic disturbances within deep fault zones. As a result, in the south, Permian and Triassic hydrocarbon deposits are grouped along regional deep fault zones.

Thus, the sub-latitudinal central zone can be considered not only as a tectonic division between the South Barents depression and Pre-Urals trough, but also as the boundary between two hydrocarbon accumulation zones: South Barents Sea and Timan-Pechora.

Sedimentary bodies formed by deltaic, sandy beach, and alluvial facies should be prospective only when they occur in zones of hydrocarbon influx; that is, within zones adjacent to the water-covered area of the South Barents depression in the north and to deep tectonic disturbances in the south.

Such analysis of the paleofacies and paleostructural conditions of sediment deposition enables us to identify zones of natural reservoirs of varying genesis and to predict which are the more interesting for prospecting.

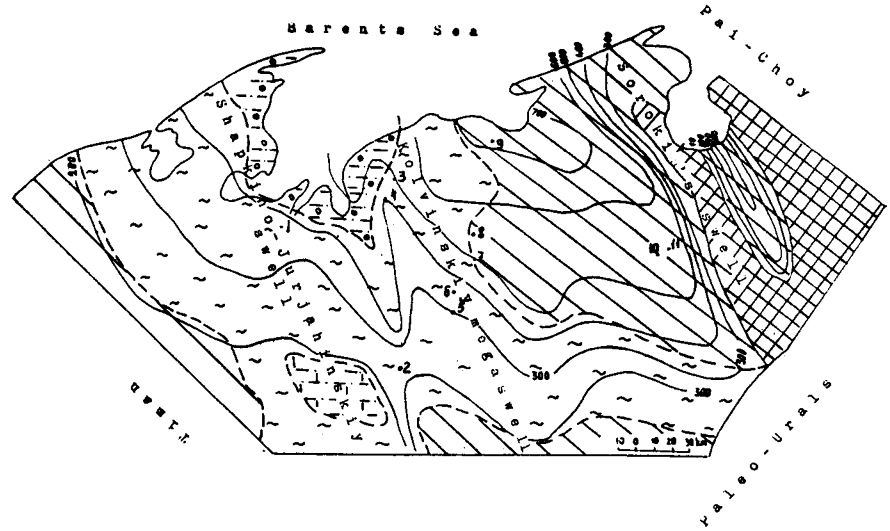


Fig.11. Lithofacies in Late Triassic time.

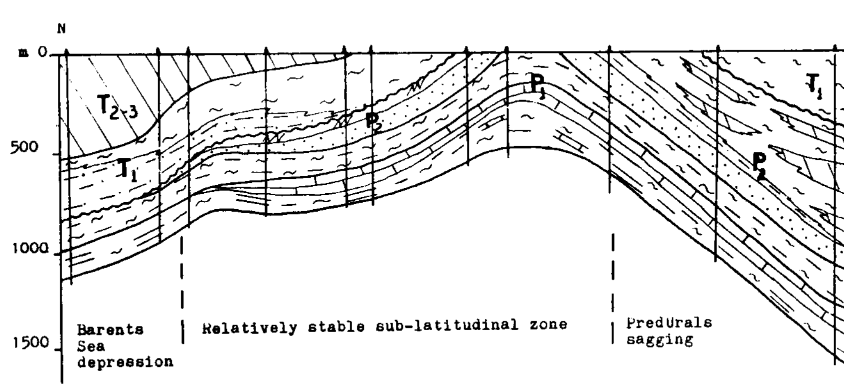


Fig.12. Paleogeological sections of Permian and Triassic deposits of Sorokin's swell.

REFERENCES

Allen, J.R.L., 1980. Sand waves: a model of origin and internal structure. Sediment. Geol., 26: 281-328.

Allen, J.R.L., 1982. Sedimentary Structures, Their Character and Physical Basis. Elsevier, Amsterdam, 2 volumes, 611 pp. and 679 pp.

Busch, D.A. (Editor), 1974. Stratigraphic Traps in Sandstones–Exploration Techniques. Amer. Assoc. Petrol. Geol., Mem. 21., 174 pp.

Coleman, J.M., 1982. Deltas: Processes of Deposition and Models for Exploration (2nd ed.). Burgess Publ. Co., Minneapolis, 124 pp.

Conybeare, C.E.B., 1976. Geomorphology of Oil and Gas Fields in Sandstone Bodies. Elsevier, Amsterdam, 341 pp.

Dedeev, V.A. and Zaporozhtseva, I.V., 1985. The Earth's Crust in the Northeastern European USSR. Nauka, Leningrad, 97 pp. (in Russian).

King, C.A.M., 1972. Beaches and Coasts (2nd ed). St. Martins, New York, 570 pp.

Krems, A.Y., Vasserman, B.Y. and Matvievskaya, N.D., 1974. The Environment of Formation and the Regularity of Distribution of Oil and Gas Pools (Pechora Basin). Nedra, Moscow, 335 pp. (in Russian).

Milanovsky, E.E., 1987. Geology of the USSR, Part 1, Introduction, Ancient Platforms and Metaplatformal Regions. Moscow State University, Moscow, 416 pp. (in Russian).

Reading, H.G. (Editor), 1986. Sedimentary Environments and Facies. Blackwell Scientific, Oxford, 615 pp.

Reineck, H.E. and Singh, I.B., 1973. Depositional Sedimentary Environments. Springer-Verlag, New York, 439 pp.

Selley, R.C., 1976. An Introduction to Sedimentology. Academic Press, London, 408 pp.

Selley, R.C., 1978. Ancient Sedimentary Environments (2nd ed.). Cornell University Press, Ithaca, 287 pp.

Stupakova, A.V., 1987. Upper Permian sandy bodies of Kolva megaswell. In: E.I. Viems (Editor), Geology, Methods of Oil and Gas Research and Exploration, no. 5, pp. 1-7 (in Russian).

Stupakova, A.V., 1991. Depositional sedimentary environments and oil-gas potential of Permian and Triassic deposits in the northern Timano-Pechora Basin. In: V.V. Semenovich and B.A. Sokolov (Editors), Geology and Geochemistry of Oil and Gas. Moscow State University, Moscow, pp. 108-121 (in Russian).