

Lithofacies features of Carboniferous – Lower Permian strata from the Pechora Sea

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ABSTRACT

This paper shows interpreted lithofacies features of Carboniferous to Lower Permian carbonate strata from the Pechora Sea. Log and core data are used to develop lithofacies schemes and construct a lithostratigraphic section across the area. Two main sedimentation phases are revealed: 1) Late Viséan-Serpukhovian and 2) Middle Carboniferous – Early Permian. There is a gap between those phases which is confined to the Early Bashkirian time. Both phases are characterized by reef sedimentation. Available well data show that during Late Viséan–Earlier Permian time, the area of reefs distribution gradually shifted from northeast to northwest and west. In Carboniferous to Early Permian time shallow sea environments changed into much deeper environments.

INTRODUCTION

Carboniferous–Lower Permian carbonate strata comprise one of the main oil and gas-bearing reservoir objectives among all discovered fields in the Pechora Sea. The emphasis of this study is on the offshore Pechora Sea portion of the Timan-Pechora Basin province of northwest Russia. Exploration and development shows the most prospective reservoirs are Asselian to Sakmarian reef buildups (Bro, 1993; Viskunova, Suprunenko, and Preobragenskaia, 2002). Additional hydrocarbon deposits also occur in the Upper Viséan to Middle-Upper Carboniferous section. The core and log data shows the variations of lithological composition, depositional environments, and facies distribution of these rocks. Results obtained during this study may highlight areas where prospective reservoirs are most likely to occur.

Core descriptions, rock samples and thin sections, and well logging data from eleven wells

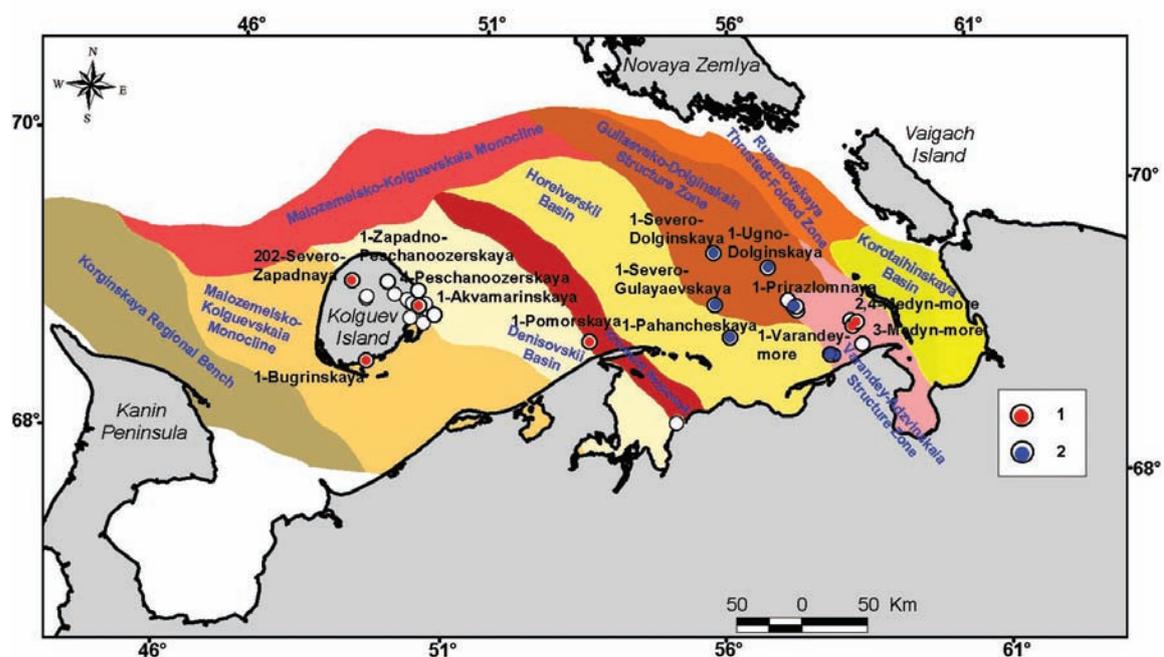


Fig. 1. Map of structural elements and well location at the Pechora sea. Deep wells: 1 – core samples, thin sections, well logging data were investigated, 2 – core description, well logging data were considered.

comprise the data for this study. Depositional environments are reconstructed from facies analyses. These wells represent the stratigraphic variations across major structural elements of the Pechora Syncline (from West to East): Malozemelsko-Kolguevskaya Monocline, Denisovsky Basin, Kolvinskii Megaswell, Horeiverskii Basin, Guliaevsko-Dolginskaya and Varandey-Adzvinikaia Structure Zones (Fig.1).

The Carboniferous–Lower Permian carbonate strata vary in thickness from 326 m in the

1-Bugrinskaya well to 620 m in the 1-Prirazlomnaya well. The age of this complex is Late Visean to Early Permian (Sakmarian, partially Artinskian). At the western part of the region, Carboniferous to Lower Permian carbonate rocks unconformably overlie Tournaisian and Upper Devonian strata (Preobragenskaia, Ustricki, and Bro, 1995). Visean rocks wedge out in a westerly direction based on seismic data (Suvorova, Viskunova, and Preobragenskaia, 2010). In contrast, in the eastern part of the basin these rocks are deposited

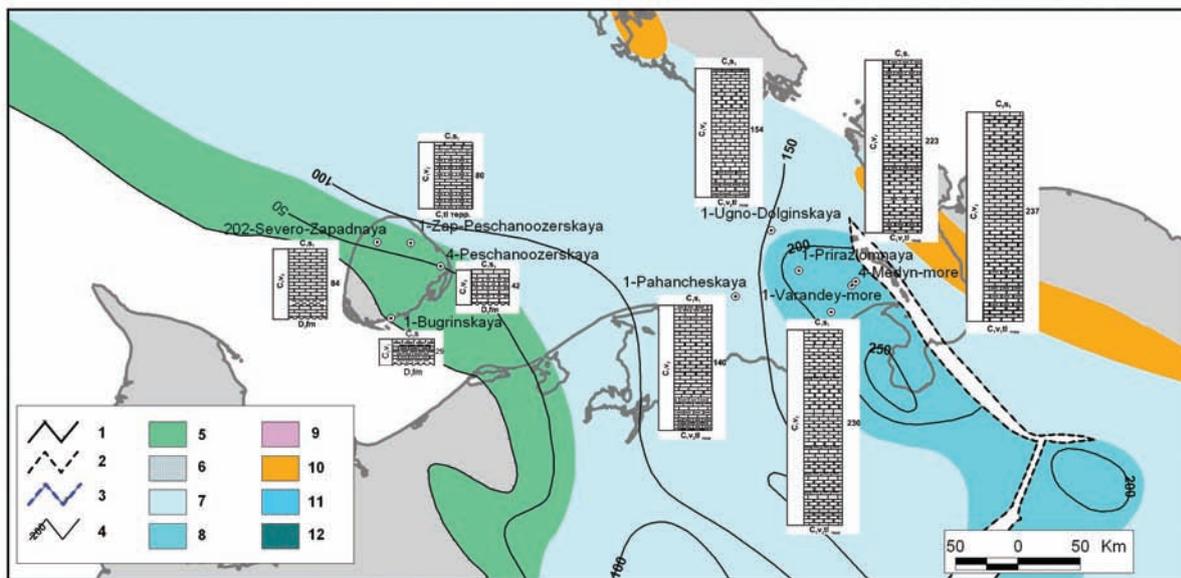


Fig. 2. Lithofacies map of Upper Visean strata. Boundaries: 1 – of modern strata distribution, 2 – strata absence, 3 - of Bashkirian strata distribution, 4 – isopachs. Environments: 5 – coastal, 6 – insular high zone, 7 - shallow shelf, 8 – depression on shallow shelf, 9 – lagoon, 10 - buildups, 11 - deep shelf, 12 – continental slope.

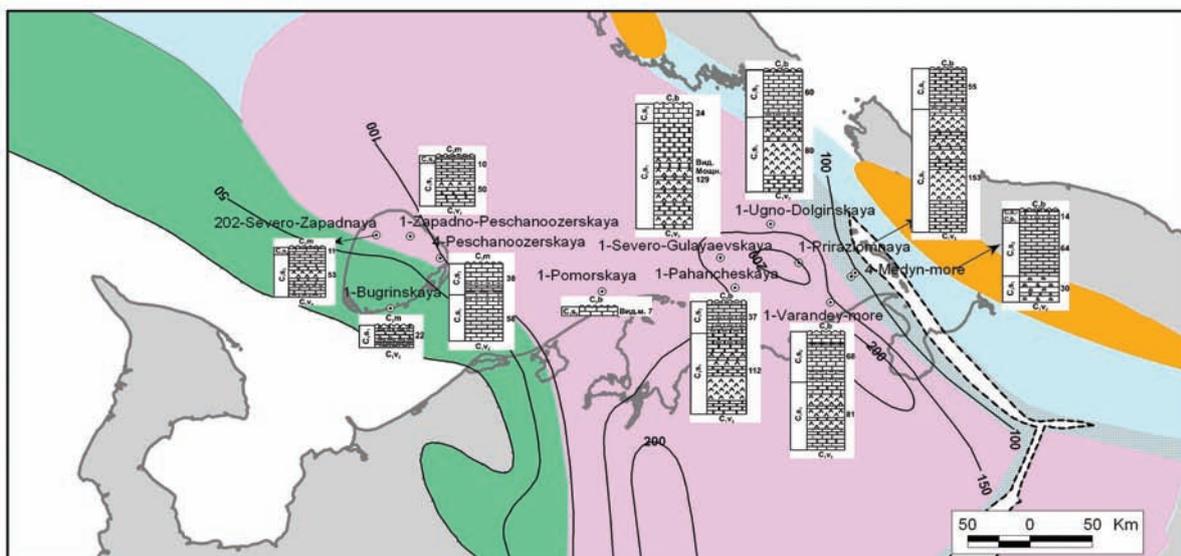


Fig. 3. Lithofacies map of Serpukhovian strata. Legend shown on fig.2.

conformably on the Devonian section in the Varandey-Adzvinskaia Structure Zone. Asselian to Sakmarian strata are overlain by Artinskian to Kungurian terrigenous rocks, and in the Medyn-Saremboj zone by Triassic argillites.

LITHOFACIES FEATURES AND ENVIRONMENTAL EVOLUTION

Early Visean of the northern Pechora basin consisted of continental and coastal environments. A marine transgression starting in the Late Visean changed the depositional condition into a shallow shelf setting, however coastal environments were preserved in the western part of the study region (Fig.2). A comparatively thick and predominantly mud-rich section on the eastern part of the shallow shelf suggests sedimentation in a deep depression in the Varandey-Adzvinskaia Structure Zone. At the end of the Late Visean sea level was lowered in the basin, and in the Medyn-Varandey zone littoral conditions with stromatolitic limestones were deposited.

In Early Serpukhovian time the sea basin became shallower. Coastal conditions were preserved in the western part of the basin. Lagoonal environments occurred over the greater part of the region (Fig.3), and sulphate-dolomite evaporites formed. At the eastern part of the basin a lagoon was bounded by an insular high zone (in modern coordinates this zone corresponds to Varandey-Adzvinskaia Structure Zone), where secondary dolomites formed by eogenetic alteration.

Upper Serpukhovian rocks across most of the area show an environment which is comparatively rich in fauna and flora such as corals, brachiopods and algae, indicating normal shallow marine environments were restored at this time.

During Visean-Serpukhovian time organogenic buildups formed in the Pechora Sea. Visean-Serpukhovian reefs can be traced in the western slope of the Urals, in southwest of Pai-Khoi (Antoshkina, 1994), and along the western coast of Novaya Zemlya (Matveev, 2008, Novaya Zemlya, 2004) (Fig.4). The distribution of these organic buildups is related to the boundary between the shallow-water Eleckaya and deep-water sediments of the Lemvinskaya formation zones. The position of this boundary has existed since the Ordovician (Sobolev,

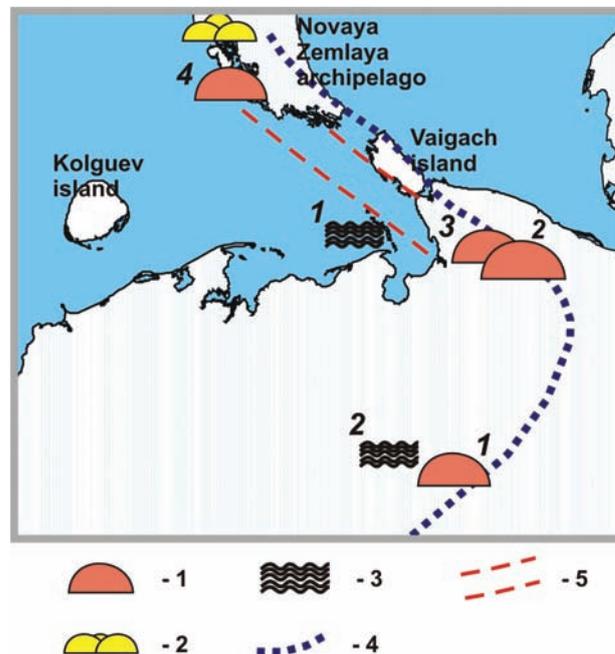


Fig. 4. Location of Visean-Serpukhovian buildups. 1- reefs: 1 - on The Bolshaya Nadota river (Eliseev, 1978), 2 - on The Sibirchata river (Antoshkina, 1994), 3 - on The Hey-Iyga river (Antoshkina, 1994), 4 - on The Chernyi cape (Novaya Zemlya, 2004); 2 - mud mounds on the Vypuklyi and Sokolova peninsulas (Novaya Zemlya, 2004); 3- stromatolites: 1 - in the Medyn-more field (Suvorova, 2010), 2 - in the Chernyshova mound (Antoshkina, 1994); 4 - paleoboundary between shallow and deep-water sediments (Sobolev, Ustrickii, Cherniak, 1985); 5 - the region, where reefs are expected.

Ustrickii, and Cherniak, 1985). We propose that the Visean-Serpukhovian buildups can be detected also in the Korotaihinskaya basin of the Pechora Sea.

The marine regression was followed by transgression in Late Serpukhovian-Early Bashkirian time, and as a result Upper Serpukhovian strata were in part eroded or simply not deposited.

In Late Bashkirian time carbonate sediments were deposited gradually from east to west across the region. In the western part of the Pechora Sea sedimentation occurred only since Late Moskovian time.

Comparatively shallow shelf environments predominated in Bashkirian and Moskovian time (Fig.5). Facies of bioclastic limestone sand and small bioherms occur in the Guliaevsko-Dolginskaya and Varandey-Adzvinskaya Structure Zones.

During Kasimovian-Gzhelian time the basin deepened (Fig.6) and shallow shelf environments

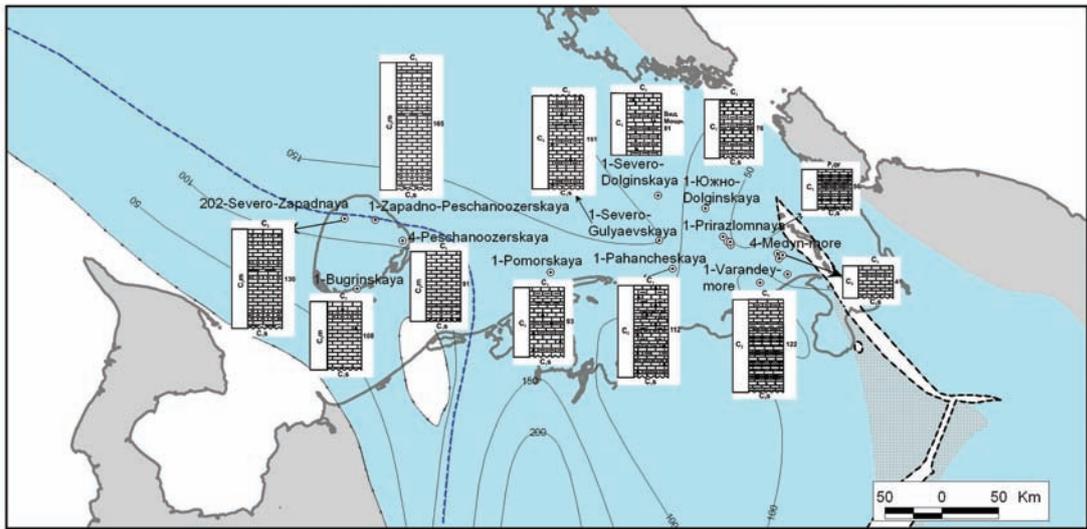


Fig. 5. Lithofacies map of Bashkirian-Moskavian strata. Legend shown on fig.2.

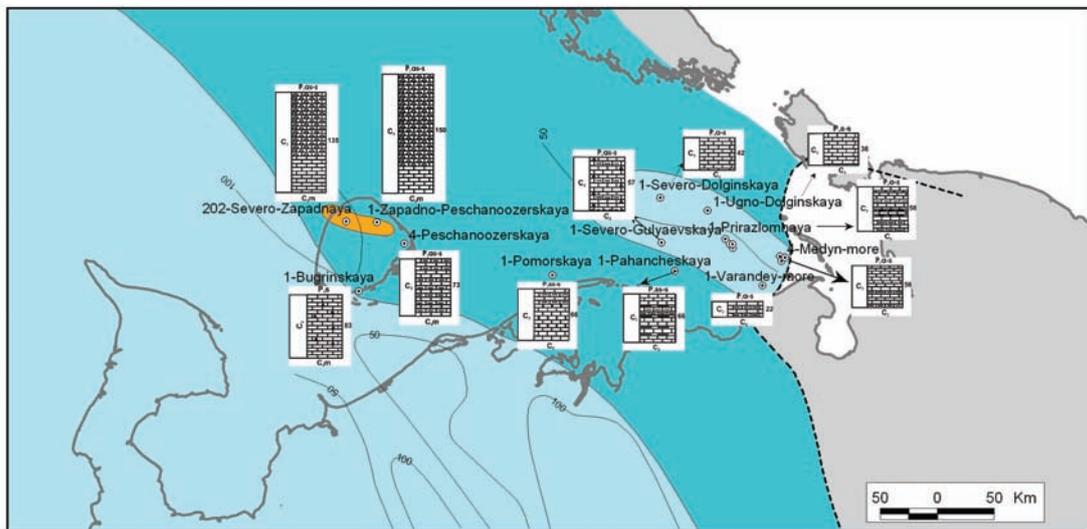


Fig. 6. Lithofacies map of Casimovian-Gzhelian strata. Legend shown on fig.2.



Fig. 7. Lithofacies map of Asselian-Sakmarian strata (By Viskunova, Suprunenko, Preobragenskaia, 2002 with changes). Legend shown on fig.2.

existed in the eastern part of the study area, where bioclastic limestones were deposited. According to published data (Preobragenskaia, Ustriski, and Bro, 1995), organogenic buildups at the western part of the region started to form in Late Pennsylvanian time.

In Early Permian time buildups were distributed to the west on Kolguev Island and to the east within the Guliaevsko-Dolginskaia and Varandey-Adzvinskaia Structure Zones (Fig.7). In the Pechora-Kolvinski, Megaswell, and Horeiverskii basins, reef buildups are observed in seismic data (Viskunova, Suprunenko, and Preobragenskaia, 2002). Seismic data also show that all lithofacies of the lower Permian are absent along the western boundary of Korotaihinskaya basin. The absence of strata is due

to post-Permian erosion.

Lithofacies schemes described in our paper can be used as a basis for predicting reservoir potential. Producing oil pools in Lower Carboniferous rocks could be associated with Upper Visean secondary dolomites, for example, such pools are present in the Medynskoe-More deposit. The porosity coefficient of these rock is 10-15%.

Oil fields with sufficient resources for commercial production from Middle to Upper Carboniferous rocks occur in the Dolginsky and Medynskoe-More fields. Oil production here is from both algal genesis rocks and calcareous sand facies that were deposited on the shelf edge. The porosity coefficient of these rocks is from 7% to 10-15%. We extrapolate that potential oil accumulations may

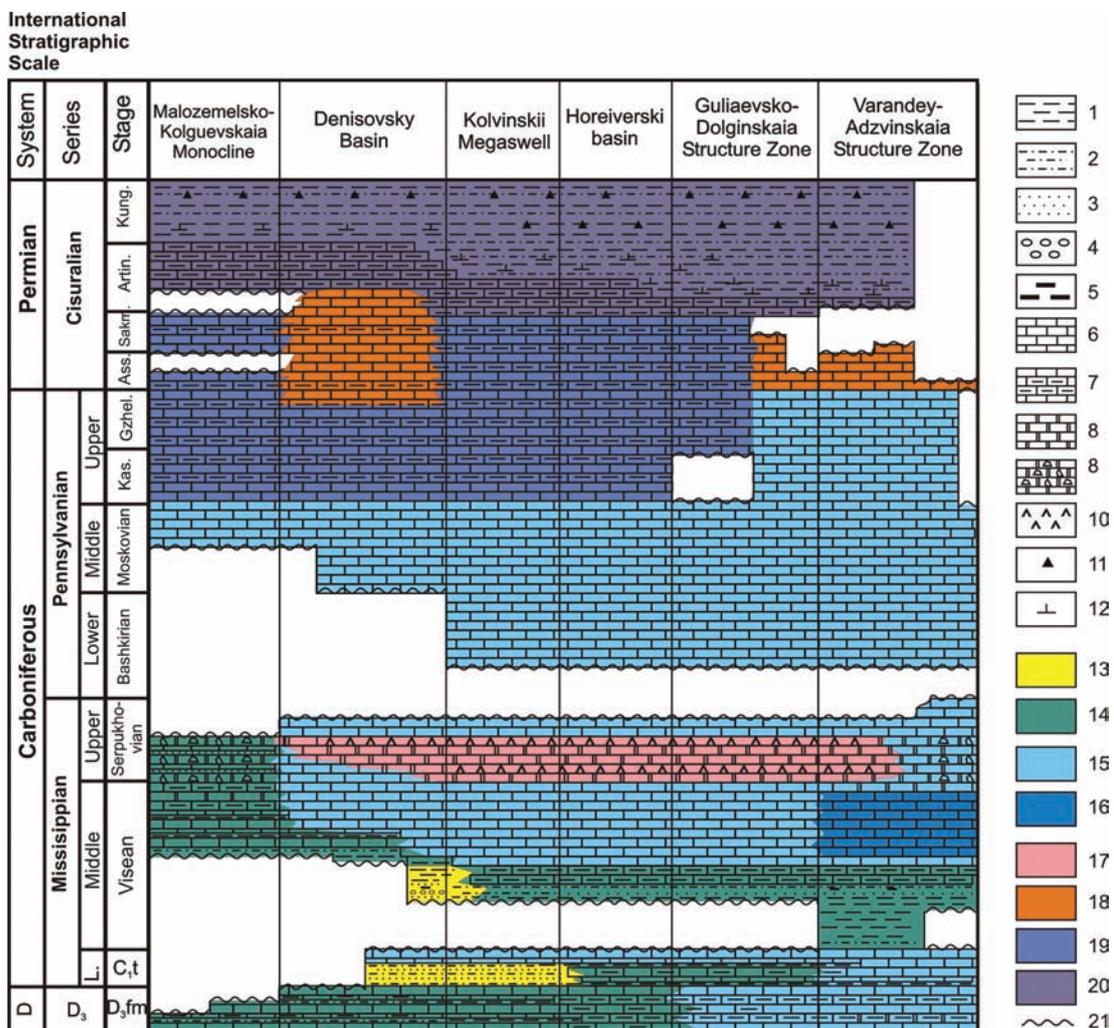


Fig. 8. Lithostratigraphic section of Upper Visean – Lower Permian strata. Lithology: 1 – claystones, 2 – siltstones, 3 – sandstones, 4 – pebbles, 5 – coal lenses, 6 – limestones, 7 – clayey limestones, 8 – dolomites, 9 – carbonate breccia, 10 – anhydrite, 11 – cherts, 12 – calcareous. Environments: 13 – continental, 14 – coastal, 15 – shallow shelf, 16 – depression on the shallow shelf, 17 – lagoon, 18 – buildups, 19 – deep shelf, 20 – shelf slope. 21 – unconformity.

occur in correlative Middle to Upper Carboniferous rocks in the north-west continuation of the Dolginsky swell.

Regional data show that the Lower Permian organogenic carbonate mound structures appear to be prospective targets for oil and gas exploration. Porosities of up to 20% are reported from similar sedimentary facies in the already discovered Prirazlomnoe, Dolginskoe, and Varandey-More oil fields. Similar prospective oil exploration targets are expected in the Kolvinsky megaswell and along the margins of the Horeiversky Basin, provided the lithologic composition, and hydrocarbon charges are similar.

CONCLUSION

Figure 8 summarizes the lithostratigraphic analysis of the evolution of Late Visean-Early Permian carbonate rocks across the northern Pechora Basin. There are two main sedimentation phases: Late Visean-Serpukhovian and Bashkirian-Sakmarian. The hiatus between these phases is confined to Early Bashkirian time in the east and Upper Serpukhovian through Middle Moskovian in the west. Carbonate facies are varied both in lateral and vertical directions. In Late Visean-Serpukhovian time coastal, shallow sea and lagoon environments predominated. The basin deepens during Bashkirian-Sakmarian time resulting in the deposition of relatively deep-water shelf sediments.

Both sedimentation phases are characterized by reef building. The distribution of reefs is related to the shelf edge boundary between shallow and deep-water environments. In particular, Visean-Serpukhovian reefs can be traced on the western slope of the Urals, south-west of Pai-Khoi (Antoshkina, 1994), and along the western coast of Novaya Zemlya (Matveev, 2008; Novaya Zemlya, 2004). Lower Permian reefs are found at the south-west border of the Denisovskii Basin (at Kolguev Island) and in the eastern part of the offshore Pechora Basin. During Late Visean-Early Permian time, the distribution of reefs gradually shifted in direction from northeast to northwest and west.

ACKNOWLEDGMENTS

Lithological and paleogeographic study of Palaeozoic strata was provided by E.G. Bro, E.N.

Preobragenskaia, V.M. Komarnicki, V.I. Ustrickii, L.G. Povysheva, E.S. Mirolubova, M.S.Zonn and others. We appreciate the thoughtful and thorough review of our paper by A. Banet, R. Blodgett and J. Clough.

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