Antarctic Science 1 (1): 51–56 (1989)

Evolution of Antarctic prospective sedimentary basins

V.L. IVANOV

SEVMORGEOLOGIA, 120 Moika, Leningrad 190121, USSR

Abstract: No less than 15–20 sedimentary basins are now known on the Antarctic continental landmass and surrounding continental shelves. Reconstruction of their tectonic and stratigraphic evolution is a specialized task. Owing to the polar position of the continent, the Pacific and Atlantic global geostructures are closely spaced there and the interplay between them is strong enough to result in hybridization of the characteristic tectonic features of the various basins. The present morphostructure of the southern polar region of the Earth is characterized by a prominent circumpolar zoning. Therefore, the sedimentary basins form a gigantic ring along the continental margin, including both the shelf proper and the edge of the continent. Within the ring, the basins are associated with different types of margins successively replacing each other, from the Mesozoic magmatic arc in the Pacific segment to the classic passive margin off East Antarctica. The formation of the sedimentary basins in the Antarctic segment of the Pacific mobile belt was a part of a single process of geosynclinal development, whereas on the craton flank the process was superposed on the continental structures by rifting during Gondwana fragmentation. During post-break-up tectonism, continental glaciation played an important part in the formation of the sedimentary basins.

[This paper was translated by R.V. Fursenko from the original Russian text, entitled *Osobennosti evolyutsii potentsial 'no neftegazonosnykh osadochnykh basseinov Antarktidy*, and published in *Geologo-geofizichskie issledovaniya v Antarktike*, ed. V.L. Ivanov & G.E. Grikurov, Leningrad: Northern Research Corporation for Marine Geology (SEVMORGEOLOGIA), Ministry of Geology of the USSR, 75–87.]

Accepted 19 September 1988

Key words: continental margins, oil and gas content, sedimentary basins.

The first data on the presence of potential oil- and gas-prone sedimentary basins in Antarctica were not published until the late 1970s–early 1980s (Grikurov 1978, Ivanov *et al.* 1982, Behrendt 1983, Ivanov 1983). However, the succeeding period was marked by rapid progress in the study of both the ice-covered Antarctic continental landmass and the surrounding shelves. The total area covered by sediments at least 1500 m thick can be estimated at 6.5–6.7 × 10^6 km^2 (Fig. 1). Different authors recognized between 7 and 20 sedimentary basins there, but concepts of the size, relations and exact boundaries of the basins are not yet completely developed. As yet no direct evidence for the presence of oil and gas has been found and, moreover, there are few data on sediment filling of the basins.

In the Ross Sea, DSDP boreholes penetrated 439 m into a section of glaciomarine sediments no older than Miocene; late Mesozoic–Palaeogene molasse-like sequences are exposed in the extreme west of the Weddell Sea Basin and in islands off the Antarctic Peninsula; molasse may also be developed locally in the cover of the basin. [The article was completed in 1987 when Ocean Drilling Project (ODP) data on the Weddell and the Sodruzhestvo seas were not available.] The only information available is confined to geophysical data obtained from multi-channel reflection seismic gravity and aeromagnetic surveys and deep seismic sounding (DSS), which define the 'geometry' and internal structure of the basins. Data on the mountain fringe of the basins, although limited, were studied in detail thus contributing towards deciphering the geologic history of the areas under study. In the situation when geochemical and lithological data are inadequate to estimate oil and gas potential directly, emphasis has to be placed on an analysis of geological history, i.e. reconstruction of the geological evolution of the sedimentary basins with a view to appraising the developmental conditions for oil and gas generation. The analysis is based on a widely-used method of geological analogies, with the concept of the Gondwana supercontinent forming a natural basis for extrapolations. An interesting attempt at geological analysis using this concept as the base was made by Alieva & Kucheruk (1985). However, they failed to find Gondwanian analogues in the evolution of the greatest Antarctic basins, i.e. those having no matches on other continents and whose evolution was not parallel to that of other basins where the model of Gondwana fragmentation could describe one, though important, episode only.

Attempts at grouping the Antarctic sedimentary basins within standard tectonic or oil-geological classifications also face similar difficulties, since some specific structural features of the basins appear to be more significant than typical ones. The specific features are as follows:

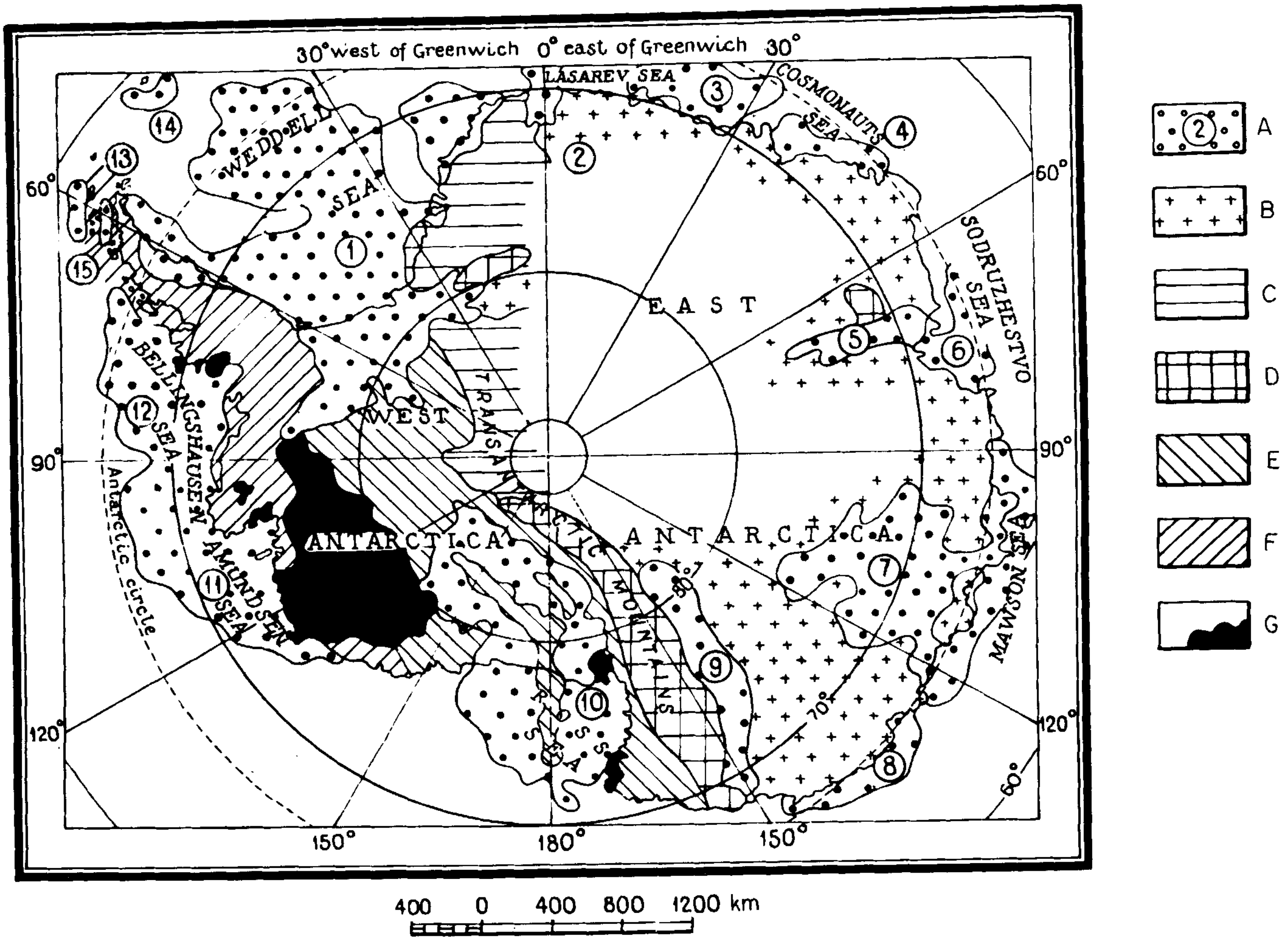

Fig. 1. Distribution of Antarctic sedimentary basins. A = Sedimentary basins: (1 = Weddell Sea (megabasin), 2 = Jutulstraumen, 3 = Riiser–Larsen Sea, 4 = Cosmonauts Sea, 5 = Lambert Glacier, 6 = Prydz Bay, 7 = Wilkes Land, 8 = D'Urville Sea, 9 = Victoria Land, 10 = Ross Sea (megabasin), 11 = Amundsen Sea, 12 = Bellingshausen basin, 13 = South Shetland basin, 14 = South Orkney basin, 15 = Bransfield Strait).

B–G = Structural basin flanks: B–D = platform covers (B = Precambrian basement complex, C = ancient cover complex, D = Middle Palaeozoic–lower Mesozoic (Beacon) platform cover).

E–F = fold systems (E = Richean–Palaeozoic, F = Andean (Upper Palaeozoic–Mesozoic).

G = Cenozoic volcanogenic complex.

First, because of the polar position of the relatively small Antarctic continent and the close spacing of the Pacific (geosynclinal-fold), Atlantic and Indo-Oceanic (mainly, platform) geostructures, the interplay between them is sufficiently strong to result in hybridization of the typical tectonic features of the basins.

Second, an important part in the evolution of most Antarctic sedimentary basins was the destruction of the continental crust and formation of the Southern Ocean. Although the entire Antarctic continent, including shelves, rests on continental crust, only East Antarctica which is an 'island', totalling 10.5×10^6 km^2 in area, represents a continent (global positive morphostructure) in a geomorphological sense.

And, third, continental glaciation was an important specific factor which not only determined the character of synchronous sedimentation, but affected oil and gas content of older strata.

Thus, the problem as applied to the Antarctic basins, amounts to the reconstruction of an individual mechanism of formation for each basin, the construction of geohistory models, and [hence the] prediction of hydrocarbon potential, rather than searching for direct analogues. Previous results obtained from such investigations were published by Ivanov (1985).

The development of lithosphere is, no doubt, a single process, i.e. part of the overall evolution of the planet.

However, until the process is fully understood, it is helpful to recognize three main 'programmes' controlling the development of the Antarctic sedimentary basins:

(1) A 'Platform-geosynclinal' programme reflecting the development of two major geoblocks: the ancient East Antarctic platform and the Antarctic segment of the Pacific mobile belt, and the interplay between these two. Programme (1) is believed to have been operative at least since the late Precambrian, i.e. since the formation of the Pacific belt as a global geostructure. The oldest evidence for the operation of programme (1) in Antarctica is the Ross system of the Transantarctic Mountains. Later, the mobile zones migrated in succession from the platform towards the present Pacific coast. Programme (1) was responsible for formation of the basement of almost all basins and related cover complexes in most basins. The position of a basin (in the platform, in the fold belt, or in the transitional zone) determined the formational and lithological composition and the age of cover complexes. In other words, the structural-formational complex, associated with programme (1), is heterogeneous not only for the Antarctic as a whole, but for many individual basins.

(2) A 'Continent-ocean' programme which relates to the destruction of the continental crust and formation of the Southern Ocean. The sedimentary basins of the passive continental margin were formed in the Atlantic and the Indian Ocean segments of the Antarctic. Their related cover complexes encompass a complete or a reduced set of facies corresponding to well-studied stages in the development of passive margins controlled by rifting. It is easy to find Gondwana equivalents of the shelf basins flanking East Antarctica, developed under programme (2). The time of operation of programme (2) was determined by the time of opening of segments of the Southern Ocean.

The basins situated in the Pacific segment of the Antarctic developed in another way. Without dwelling on the difficult problem of the age of the Pacific Ocean, we must note that any reconstruction of Gondwana shows that both before and after break-up, the present Pacific margin had never been in contact with any other landmass, but represented a fragment of the active continental margin of the supercontinent. On the Atlantic margins, the formation of sedimentary basins was superposed on the continental structures as a secondary, relatively independent process, but on the active margin this formation is an integral part of a continuous process of basin formation and deformation. In other words, programmes (1) and (2) could hardly be separated for the basins situated in the Pacific segment of the Antarctic.

(3) A 'Continental glaciation' programme which is related to the process of Antarctic glaciation during the past 20–25 Ma. Continental glaciation was triggered partly by geological processes. The formation of circum-Pacific currents, which sharply limited heat exchange between the Southern Ocean and equatorial waters, was caused by the neotectonic reorganization of the south polar region of the Earth and in particular by the opening of the Drake Passage. Glaciation in turn strongly affects synchronous geological processes. Glaciomarine complexes, laid on the Antarctic shelves, are starved of sediment; thus breaks, impersistent sections, abundant coarse clastic facies and glacial scouring are typical of these complexes. In the inland basins, the action of programme (3) may have been responsible for partial destruction of the cover, glacioisostatic redistribution of deposits, stimulation of downwarping and gas-hydrate formation.

Continental glaciation on such a scale is a purely Antarctic phenomenon but, if the effects of Antarctic glaciation are removed, we can find some features common to the polar regions both in terms of the evolution of the continental crust and the formation of the oceans. In any case, the distribution of the platform and fold structures of the landmasses exhibits no circumpolar or other central-type zoning. Linear geosynclinal-fold zones align mostly along the strike of the relevant segments of the Pacific mobile belt, i.e. sublongitudinally. At the same time, the general morphostructure of the polar regions of the Earth is governed by a distinct circumpolar symmetry, although it is inversely so with a landmass surrounded by ocean on the Antarctic and the landmasses in the Arctic. Concepts of the arctic geodepression have been widely developed by Yu. E. Pogrebitsky. In the Southern Hemisphere, the circumpolar morphostructure is controlled by the polar position of the continent with the surrounding deep troughs and mid-oceanic ridges displaying latitudinal, concentric zonal orientation. The predominantly longitudinal global structures of the three major oceans of the Earth become sublatitudinal towards the South Pole. Throughout the Mesozoic and Cenozoic, the 'continent-ocean' programme may have taken place in the polar regions within the circumpolar geodynamic systems.

In both the north and south, the sedimentary basins, situated on the continental shelves, form gigantic rings controlled by a complex combination of the 'platform-geosynclinal' and 'continent-ocean' programmes. Particularly thick sedimentary covers were formed where young continental margins were superposed on older zones of pericratonic submergence or on other regions of platform sedimentation (Barents Sea, Kara Sea and Weddell Sea).

Each programme is recorded in structural-lithological complexes (corresponding to sequences of seismic velocity layers), similar to those in genetically-related Gondwana and arctic sedimentary basins. Since a complete review of the evolution of all the Antarctic sedimentary basins is beyond the scope of the present paper, we have restricted ourselves to an analysis on the basis of the above scheme.

Inland basins

The simplest evolutionary pattern, dominated by programme (1) can be recognized in the inland basins of Wilkes Land (a depression in crystalline basement) and Victoria Land (a similar structure, presumably covered with Beacon deposits, with superposed young compensatory troughs which resulted from the uplift of the Transantarctic Mountains and their sub-ice equivalents). In both cases, there is evidence of pre-break-up rifting. The 'continent-ocean' programme has had little affect on the evolution of the basins and information on programme (3) is not yet available.

Programmes (2) and (3) determined the evolution of the basins which border East Antarctica in a narrow, discontinuous semi-circle from the D'Urville Sea to the north-eastern end of the Weddell Sea shelf. These are typical basins of the passive continental margins, equivalents of which are extensively developed on the Gondwana continents. The formation of the associated cover complex was related to rifting in its complete or reduced form. The post-break-up stage of evolution of the basins was dominated by glaciomarine deposition.

Prydz Bay

The structure of the cover on the Prydz Bay shelf has been most widely studied. Seismic data, obtained by the 31st and 32nd Soviet Antarctic Expeditions are still under study but a preliminary analysis permits the recognition of two sedimentary basins, separated by a large basement high. The east basin is a direct extension of the continental Lambert Glacier rift graben. It is characterized by a prominent sublongitudinal lineation, steep flanks, submergence of the basement down to 10–12 km, the presence of graben-like structures arranged in a feather pattern, depressed bottom topography, and elevation of the Moho discontinuity beneath the axis of the depression. By contrast, the west basin is sublatitudinal and parallel to the outer shelf boundary; its structure is simpler, plunges are gentle and linear forms are less common.

The seismic velocity layers within the cover sequence in both basins can be subdivided into three, but the relative significance of each unit is different for the east and the west basins. In the east basin, the lower sequence (III), having layer velocities 3.6–5.2 km s^{-1} accounts for 70–80% of the cover thickness; the sedimentary complex proper fills basement depressions and there is evidence for synsedimentary structural deformation. The complex, whose basal parts are formed of [equivalents of] the Beacon (Permian) coal measures, is presumably represented by continental, lagoon and shallow marine facies, formed during the pre-break-up stage of rifting. Sequence II (2.3–3.0 km s^{-1}) is coilogenic [= forms the upper fill] in both basins. It corresponds to the stage of development of the passive continental margin at the time of opening of the adjacent Southern Ocean sector (130–110 Ma ago, according to different authors). Finally, the late Oligocene-Quaternary upper seismogeological sequence I (1.6–2.3 km s^{-1}) corresponds to the stage of continental glaciation.

Thus, the formation of the cover of the east basin during the first stage (sequence III) followed the transcontinental Lambert Glacier rift programme. At that time, latitudinal rifts — lines of weakness for subsequent Gondwana fragmentation — may have formed in the west basin. After the opening of the Southern Ocean, the character of evolution of both basins become more comparable, as they were subject to a single process of continental margin formation.

Weddell Sea

The Weddell Sea sedimentary megabasin is a gigantic heterogeneous sedimentary body consisting of several genetically unrelated basins. This crucial factor, in the author's opinion, explains the failure of attempts to 'squeeze' the entire megabasin into a single tectonotype within generally accepted structural-tectonic and oil-geological classifications. The megabasin has no Gondwana matches, and on reconstructions of Gondwana the region is problematical.

There are no true equivalents of the Weddell Sea megabasin among known sedimentary basins of the world; although its tectonic position resembles that of the Gulf of Mexico. The two basins are situated where the continents narrow and the Pacific fold structures and the Atlantic continental margins approach one another. The basins are flanked by Cenozoic magmatic arcs (Scotia and Antilles, respectively), Mesozoic–Cenozoic fold systems (West Antarctic–Mexican Cordillera), and ancient platforms (East Antarctic and North American), including elements of Palaeozoic fold structures (Pensacola and Ellsworth Mountains and Appalachians). If the spreading mechanism is mentally applied to link the structural deeps of the Gulf of Mexico and the Atlantic Ocean, one obtains structurally an almost mirror reflection of the Weddell Sea region. The sedimentary superbasin of Gulf of Mexico is divided into a number of individual elements (basins): the Gulf of Mexico basin proper, pre-Appalachian and pre-Cordillera foredeeps, island-arc trough, etc.

Data available on the Weddell Sea enable us to recognize at least four constituent sedimentary basins here.

The Princess Martha Coast basin, situated in the extreme north-east of the shelf east of 25°W, evolved as a relatively simple piece of Gondwana continental margin, similar to the above-mentioned Prydz Bay west basin. The sedimentary depression, filled with sediments having seismic velocities 3.8–5.0 km s^{-1} (Hinz & Krause 1982) and confined by a seaward ridge of marginal-shelf basement stretches along a narrow shelf. The depression probably corresponds to the pre-break-up stage of rifting and correlated with sequence III in Prydz Bay. Above comes a coilogenic succession of marine (Upper Jurassic–Palaeogene?) and glaciomarine sediments having velocities 2.0–3.8 km s^{-1} it is separated from the underlying deposits by the Weddell Sea unconformity and overlies basement rises. The succession is analogous to sequences II + I in Prydz Bay, was deposited on an opened continental margin and its upper part accumulated under conditions of continental glaciation. This scheme holds true not only for the Gondwana margins: according to Hinz & Krause (1982), equivalents of the (?) Jurassic Weddell Sea unconformity are traceable as far as the North Atlantic.

A complex combination of programmes (1) + (2) + (3) governed the development of the south Weddell basin, which occupies most of the shelf and is comparable with the Gulf of Mexico depression. The bottom topography forms a single plateau, bordered by a semicircle of deep narrow troughs on landward side. A gigantic crustal depression, complicated by sublongitudinal and sublatitudinal troughs, is present in the basement surface. Its eastern margin is underlain by the high-velocity Precambrian crystalline basement, whereas the folded basement, up to 5–10 km thick and presumably composed of Riphean–lower Palaeozoic moderately deformed or undisturbed sequences, occurs everywhere between the crystalline surface and the acoustic basement. Over an area of about 1×10^6 km^2, the basin cover represents a single sedimentary body, ubiquitously divided into three seismogeological sequences: lower (7–8 km thick, seismic velocities 4.3–5.1 km s^{-1}); middle (3–4 km thick, 3.5–4.0 km s^{-1}); and upper (up to 1.5 km thick; 2.5–2.7 km s^{-1}). The area, now occupied by the basin, may have evolved as a single area of downwarping for a long time, although the mechanism of cover formation may have been different in various structural zones. This holds true especially for the lower seismogeological sequence: Palaeozoic–early Mesozoic in age, it includes fills of earlier basins, developed in the area of pericratonic subsidence, and covers of earlier troughs, that resulted from the uplift of the Pensacola and Ellsworth mountains. Both kinds of sediments were deposited under programme (1). However, the sequence also includes sediments that accumulated during the early stages of development of rift grabens, associated with the evolution of the continental margin, i.e. programme (2).

Sediments filling the Filchner rift graben may be compared with deposits of the Mississippi palaeodelta. A pre–Upper Jurassic regional unconformity, formed prior to the opening of the Atlantic sector of the Southern Ocean, unites these heterogeneous facies to form a single complex, and the further simultaneous subsidence resulted in levelling of the seismic parameters. The middle sequence is believed to represent an Upper Jurassic–Oligocene cover complex proper, related to the evolution of the continental margin following programme (2); it is of particular interest with respect to the presence of oil and gas. Finally, programme (3) is responsible for the formation of the upper, coilogenic complex, primarily made up of glaciomarine sediments and separated from the underlying strata by a regional unconformity, related to the onset of glaciation (fall of sea level, erosion, etc.).

Basins adjacent to the eastern continental margin of northern Antarctic Peninsula and the South Orkney Islands may be considered as back-arc basins of the active margin.

Pacific margin

Sedimentary basins of the Pacific margin of Antarctica are related to the evolution of the Mesozoic West Antarctic geosynclinal-fold system, although each basin has specific individual features which characterize its development. The Bellingshausen basin and the Amundsen Sea basin are situated on the frontal (seaward) flank of the mountain system and extend parallel to the general trend of the fold structure. The basins could be regarded as a frontal zone of the West Antarctic fold system (or, in other terms, those of island arcs), however, the discrepancy between the time of folding and the age of the sedimentary cover suggests that this is not the case. Folding ended in the Mesozoic, thus marking the cessation of the active continental margin activity in this area. The sedimentary cover, on the Bellingshausen shelf can be subdivided into two seismogeological sequences (on the continental slope, a third sequence is present at the base), and is relatively young — early Miocene–Pleistocene (Kimura 1982). This is probably a continental margin of the Colombia type (after Belousov (1982)) where a young area of shelf sedimentation is superposed on an extinct active margin (with an incomplete set of morphostructural elements), similar to the 'Atlantic' model. As a result of belonging to the circumpolar geostructure, the shelf basins are extremely wide (300–500 km).

Ross Sea megabasin

Unlike the above-described basins, situated on the outer shelf, the Ross Sea megabasin forms a deep embayment in the landmass and lies in a gigantic depression stretching from the Pacific to the Atlantic. The Atlantic end of the depression is occupied by the Weddell Sea megabasin, but the tectonic position of the latter is different. With good reason, the Weddell Sea megabasin is classified as a transitional area between the platform and the geosynclinal-fold system, or as an area of pericratonic subsidence. By contrast, the whole Ross Sea megabasin lies within the Pacific mobile belt *sensu lato*, with the Ross system of the Transantarctic Mountains as its extreme and oldest branch. A wide distribution of 'Caledonian' structures within the megabasin basement has recently been proved (Traube 1987).

The Ross Sea megabasin has a lineation, which is related to the trend of the 'Pacific' structures and expressed in basement bottom and top topography, as well as in the sedimentary cover. Unlike that of the Weddell Sea megabasin, the sedimentary cover of the Ross Sea megabasin does not form a single body, but fills three narrow elongate basins, separated by linear basement rises. The base of the sedimentary cover is no older than latest Mesozoic. The cover structure, including the youngest horizons, suggests that sediments accumulated there simultaneously with the formation of the interbasinal linear basement rises. The above and many other factors point to a striking similarity with the Bering Sea basin (Golubev & Ustinov 1981). In the author's opinion, the Ross Sea megabasin can be considered as a combination of intermontane troughs of the fold area, where orogeny continued until the neotectonic stage, simultaneously with the uplift of the Transantarctic Mountains system. In the late Cenozoic, sedimentation became more platform in character because of glacal isostatic depression of the region. The inferred break away of the New Zealand block of Gondwana, initiated 80–85 Ma ago (Craddock 1982), involved a progressive subsidence of the whole complex fold structure and the formation of a young Gondwana-type continental margin. The east Ross basin (Traube 1987) is the only Ross Sea basin where the thickness of upper cover sequences increases towards the continental slope and that of lower sequences decreases. Basement rises on the outer Ross Sea shelf and on Iselin Bank are typical of a passive margin. Traube (1987) considered cover sequences of the megabasin as deposits, respectively, of the trough and basinal stages of development of rift structures, associated with the fragmentation of Gondwana.

In any case, the evolution of the Ross Sea sedimentary megabasin has resulted from a complex combination of 'platform-geosynclinal' and 'continent-ocean' programmes, including the 'continental glaciation' programme at the during Miocene–Holocene times.

Conclusions

The proposed scheme of historic-geological analysis permits:

a. reconstruction of palaeotectonic and palaeogeographic environment of formation of the Antarctic sedimentary basins, both of known and inadequately known structure;
b. modelling of possible facies of lithology of the sedimentary cover, palaeothermobaric conditions and, hence
c. more substantiated assessment of their hydrocarbon potential, as compared to 'general geological' or more specific, but unilinear Gondwana analogues.

References

ALIEVA E.R. & KUCHERUK, E.V. 1985. Geodynamicheskie rekonstruktsii kak metod prognoza neftegazonosnosti slaboizuchennykh regionov (na primere Antarktidy). [Geodynamic reconstructions as a method of hydrocarbon potential prediction in unknown areas (with exemplifications from the Antarctic).] *Izvestiya Akademii Nauk SSSR*, Ser. Geologicheskaya, **9**, 100–110.

BEHRENDT, J.C. 1983. Petroleum Mineral Resources of Antarctica. *United States Geological Survey Circular*, No. 909, 3–24.

BELOUSOV, V.L. 1982. *Transitional zones between continents and oceans*. Moscow: Nedra, 152 pp. [In Russian.]

CRADDOCK, C. 1982. Antarctica and Gondwanaland. *In* CRADDOCK, C., *ed*. *Antarctic Geoscience*. Madison: University of Wisconsin Press, 3–13.

GOLUBEV, V.M. & USTINOV, N.V. 1981. Stroenie i razvitie Beringovomorskogo osadochnogo megabasseyna. [Structure and evolution of the Bering Sea sedimentary megabasin.] *In Osadochnye basseyny i ikh neftegazonosnost'. Tezisy dokladov IV Vsesoyuznogo seminara MGU. Moscow. [Sedimentary basins and their oil and gas content. Abstracts of IV All-Union seminar at Moscow State University.] Moscow*, 24–25.

GRIKUROV, G.E. [ed.] 1978. *Tektonicheskaya karta Antarktidy*. [Tectonic Map of Antarctica.] 1:10 000 000. Leningrad: Ministry of Geology of the USSR.

HINZ, K. & KRAUSE, W. 1982. The continental margin of Queen Maud Land, Antarctica: Seismic sequences, structural elements and geological development. *Geologisches Jahrbuch*, Reihe E., **23**, 17–41.

IVANOV, V.L. 1983. Antarctic sedimentary basins and their preliminary structural and morphological classifications. *In* OLIVER, R.L., JAMES, P.R. & JAGO, J.B., *eds*. *Antarctic earth science*. Canberra: Australian Academy of Science & Cambridge: Cambridge University Press, 539–544.

IVANOV, V.L. 1985. Prediction of the oil and gas potential of Antarctica on the basis of geological conditions. *Polar Geography and Geology*, **9**, 116–131.

IVANOV, V.L., GRIKUROV, G.E. & KAMENEVA, G.I. 1982. Tektonicheskaya evolyutsiya i stroenie osadochnogo chekhla mel'fovykh basseynov Antarktiki. [Tectonic evolution and structure of the sedimentary cover of shelf basins, Antarctica.] *In Tezisy dokladov na 2 Vcesoyuznom sbezde okeanologov. Leningrad. [Abstracts of Second All-Union Congress of Oceanologists, Leningrad.]* 7 (2), 83–84.

KIMURA, K. 1982. Geological and geophysical survey in the Bellingshausen Basin, off Antarctica. *Antarctic Record*, **75**, 12–24.

TRAUBE, V.V. 1987. Osnovnye cherty tektonicheskogo stroeniya megabasseyna Morya Rossa. [Main features of the tectonic structure of the Ross Sea megabasin.] *Antarktika*, No. 26, 72–82.