THE GEOLOGY OF FRANZ JOSEF LAND ARCHIPELAGO, RUSSIAN FEDERATION

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ABSTRACT

Franz Josef Land is part of the northern extension of the East-Barents syncline that has been uplifted and now forms part of the fragmented margin of the Barents Shelf. Troughs of rift origin separate the islands, which are formed of deeply subsided median massifs overlain by thick sedimentary sequences. Two types of stratigraphic sections are found in Franz Joseph Land. The "rift" section consists of a thin (1900 m) cover of Mesozoic and Paleozoic strata; the "nonrift depocentre" section is composed of Middle Triassic to Late Jurassic and Hauterivian sediments that may reach a thickness of 10-12 km. Both types of sections are overlain unconformably by Barremian to Albian basalt sheets interbedded with coal-bearing sediments. This plateau basalt formation also includes doleritic and gabbro-doleritic dikes and sills. Contact metamorphism is observed within a few tens of meters of the contact. Faulting and diapirism is also observed. In terms of geomorphology, lithostratigraphy, volcanism, and its germanotype tectonics, Franz Josef Land is similar to East Svalbard and the Sverdrup basin.

INTRODUCTION

Franz Josef Land is a multiisland archipelago that occupies an area of about 25,000 km^2 and, together with northern Svalbard, is an Arctic outpost of the European continent formed by the uplifted and highly broken northern margin of the Barents Shelf.

Our knowledge of the geological structure of the archipelago is based primarily on (1) the results of geological field expeditions of Koetlitz in 1894-97, Nansen in 1896-97, Spizharsky in 1933-34, Dibner and Razin in 1953 and 1956-57, Shulgina and Dibner in 1976, and Ditmar and others in 1981; (2) the interdisciplinary study of cores from three boreholes by Shkola, Bro, and Preobrazhenskaya in 1977-82; (3) aerial observations along the perimeter of all the islands by Dibner in 1953; (4) aeromagnetic profiling by Levin and others in 1962; and (5) offshore geological exploration by Ermolaev in 1935-36 and Dibner in 1957 (Dibner, 1970; Gramberg et al., 1985; Preobrazhenskaya et al., 1985).

DISCUSSION

The islands and marine basins of Franz Joseph Land belong to the northern termination of the East Barents syncline, which was formed from the underlying asthenospheric lens by compensatory subsidence of the lithosphere as a result of heat and mass transfer (Dibner, 1989). This resulted in the formation of a dense system of rifts, which is reflected in the present-day geomorphology of the archipelago as numerous grabens and troughs (Fig.1). These relatively deep depressions separate and border individual islands and groups of islands, which are formed by the uplift of deeply subsided median massifs and depocentres. Therefore, two types of sections, "rift" and "nonrift depocentres" (NRD), are recognized in the sedimentary cover of Franz Joseph Land.

The rift section was penetrated by the Nagurskaya borehole on Alexandra Land, along the subaerial continuation of the Severnaya Bay channel, which seismic surveys indicate is formed by a north-south striking graben (Kovaleva et al., 1974). The borehole penetrated a relatively thin cover in which individual strata of Mesozoic and Paleozoic sediments are separated by lengthy geochronological breaks. Below the Barremian to Albian basalt layers, the borehole penetrated Middle Triassic, Early Triassic, Late Carboniferous (uppermost Carboniferous, according to the American classification), and Early Carboniferous strata. At a depth of 1900 m, the borehole encountered a Vendian basement complex of metamorphic rocks of the greenschist facies.

NRD sections are present in the Hayes and Severnaya boreholes on Hayes and Graham Bell Islands, respectively (Fig.1). Structurally and geomorphologically, the sections are median massifs, and logging revealed their strata belong to depocentre. The boreholes encountered a thick accumulation of predominantly silty Late Triassic and Anisian (Middle Triassic) sediments totalling 3400-3500 m in apparent thickness. On nearby islands (Wilczek Land and Hall Island), these beds are overlain by predominantly sandy Early Jurassic strata, Middle and Late Jurassic sand-silty and clayey sediments, and Hauterivian variegated beds, totalling about 800 m in thickness. These data and the results of seismic surveys in the adjacent offshore suggest a thickness of 10-12 km, possibly greater, for the sedimentary cover in the nonrift depocentre of Franz Joseph Land. This cover includes pre-Anisian Triassic deposits and, by analogy with central and southern parts of the Eastern Barents syncline, the whole Paleozoic. Furthermore, the NRD cover is believed to be underlain by an ancient (pre-Vendian) basement high compressed into cells within a branching system of Baikalian (Late Proterozoic) folding, which controlled the emplacement of the above-mentioned rifts (Fig.2).

Study of the cores revealed peculiar physical properties of the sedimentary cover of Franz Joseph Land. The heat flow is as high as 75 mW/m^2, i.e., almost twice

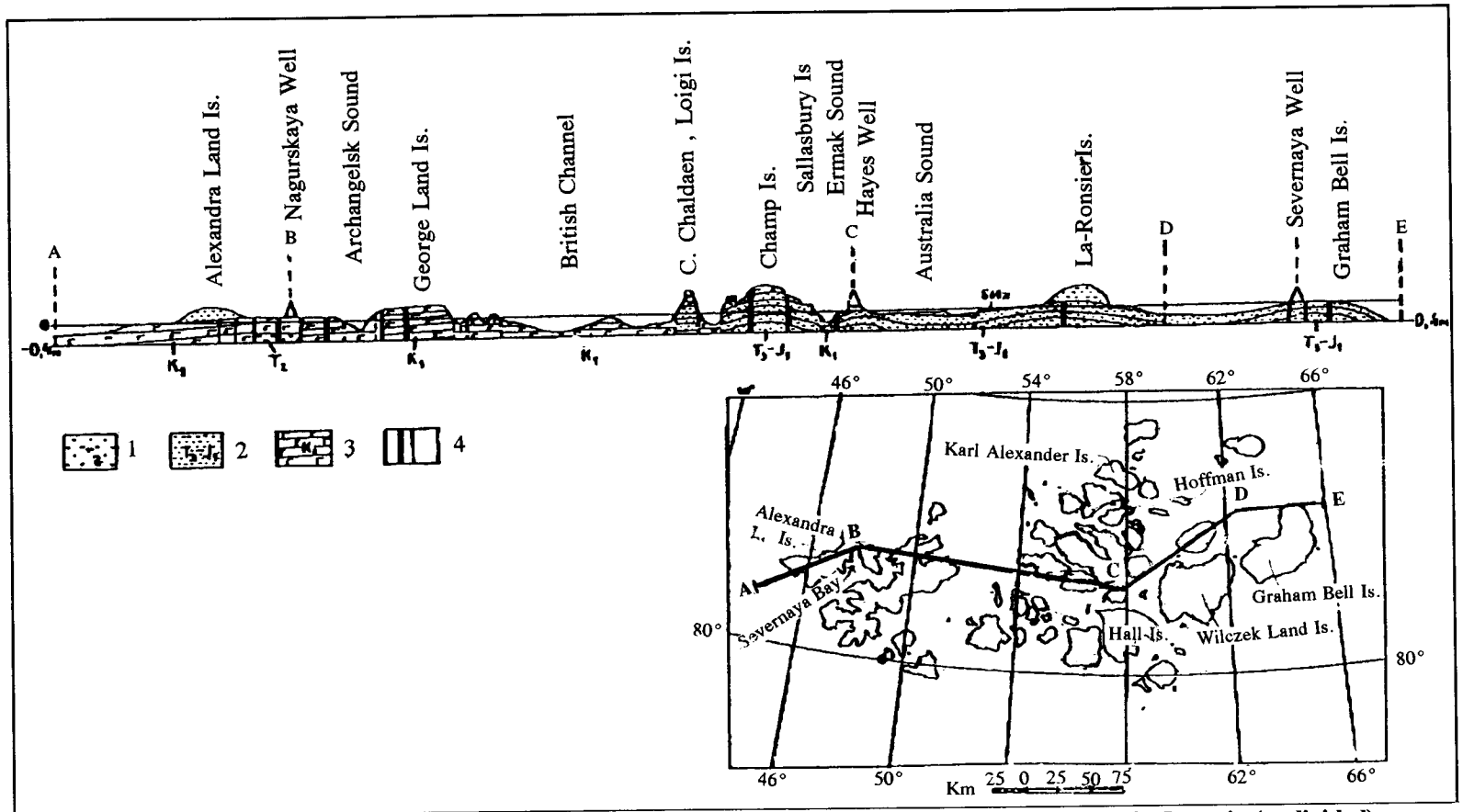

Fig.1. East-west geological profile across Franz Josef Land. 1 - Middle Triassic, 2 - Late Triassic - Early Jurassic (undivided), 3 - Early Cretaceous (basalt sheets), 4 - dolerite dikes.

as high as on the southern Barents Shelf. Therefore, the thickness of early catagenesis zones probably is reduced. For example, ranks (carbonification stages) "Д" (highly volatile bituminous coal C) and "Ж" (highly volatile bituminous coal A) are separated by an interval of only 300 m in the Nagurskaya Borehole. Densities and seismic-wave velocities increase rapidly down section. Thus, in the Hayes borehole, densities increase with a steep gradient to a depth of 1700-1800 m; below this depth, however, there is practically no increase. In the Severnaya borehole, the steepest gradient in the increase in seismic velocities occurs at a depth of 1000 m. High nitrogen and helium content, probably of deep-seated origin, were found in the composition of the gas.

Both the rift and NRD sections are overlain by a platformal cover, which is composed of the previously mentioned Barremian to Albian basalt sheets, interbedded with coal-bearing sediments. These extrusives are the main constituent of the plateau basalt formation of Franz Joseph Land, which--over a broader geochronological interval--includes hypabyssal intrusive facies represented by dolerites and gabbro-dolerites, including leucocratic and quartz gabbro-dolerites and tuff breccias (Tarakhovsky et al., 1980). It also includes 80-100-m thick doleritic and gabbro-doleritic dikes of three generations with characteristic swells that are rich in magnetite and sills. Alteration of host rocks was observed within a few tens of meters of the contact. Alteration of organic matter was traced for dozens of meters.

Isotopic dating of the dikes and sills exposed in boreholes suggest they were emplaced on Alexandra Land between 203 ± 14 and 94 ± 8 Ma (Sinemurian to Cenomanian). On Hayes Island, basic magmas were intruded during the Middle Jurassic to Late Cretaceous, whereas on Graham Bell Island intrusion continued

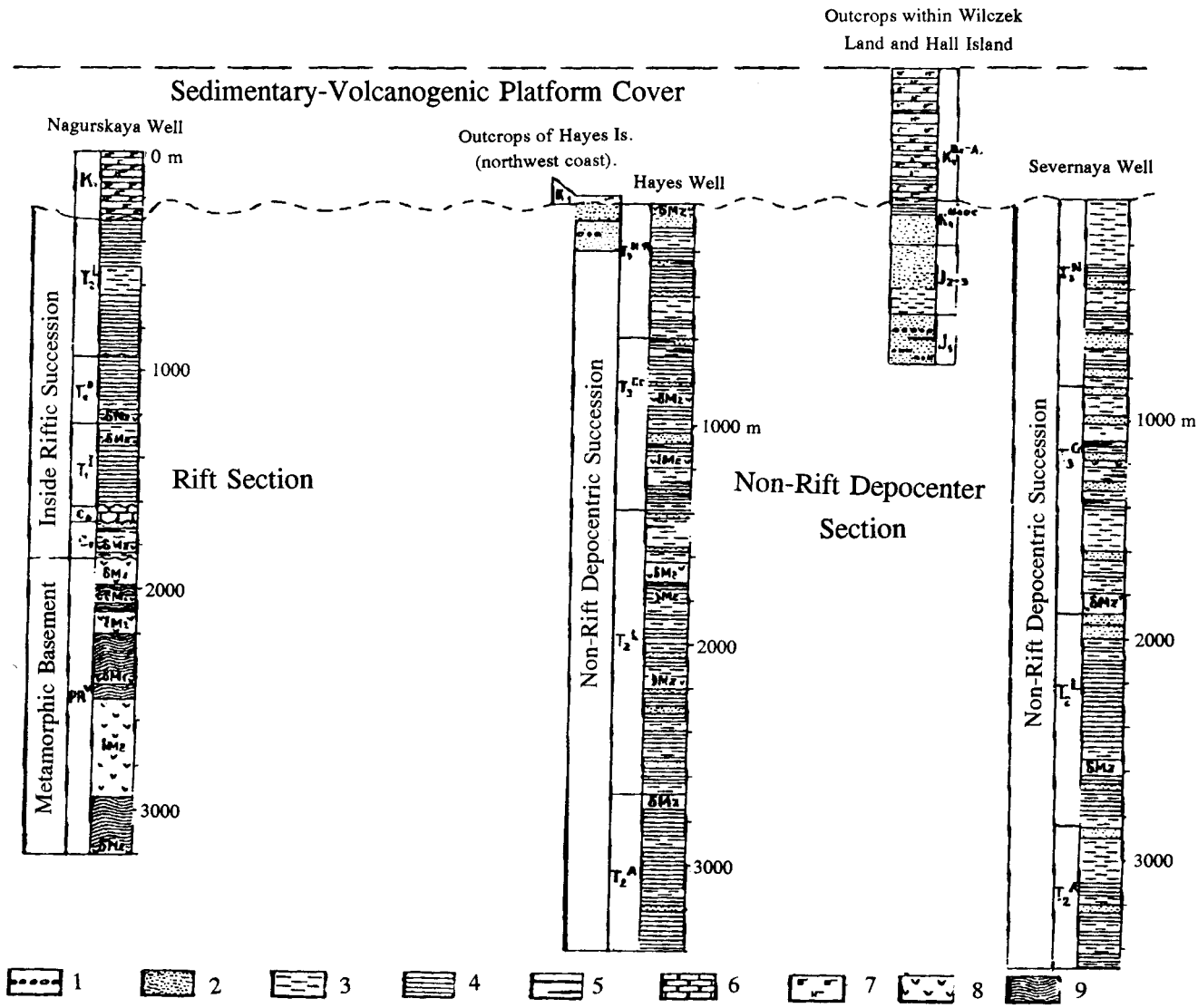

Fig.2. Rift and NRD sections of the sedimentary cover of Franz Josef Land. 1 - conglomerates, 2 - sand, sandstone, 3 - silt, siltstone, 4 - clay, claystone, 5 - coals, 6 - limestone, 7 - basalt sheets, 8 - dolerite sills, 9 - schist and quartzite.

throughout the Cretaceous and Early Paleogene (Tarakhovsky et al., 1983). Direct geological observations on many other islands of the archipelago indicate that the hypabyssal intrusions were emplaced into Late Triassic, Jurassic, and Cretaceous successions, including the Early Cretaceous extrusive and sedimentary strata; a dike was found on Hoffmann Island that cut Cenomanian sandstone. Thus, hypabyssal magmatism is believed to have rejuvenated eastward and northward.

Basaltic flows and sheets rest on both rift and NRD sections with angular unconformity and large stratigraphic hiatus. Isolated exposures of the marine Cenomanian and Neogene are known to lie stratigraphically above the basalts on Hoffmann Island.

Marine facies are most typical of the Early and Middle Triassic; the Middle-Late Jurassic; and, in part, the Carnian, Norian (Late Triassic), and Cenomanian (early Late Cretaceous). Continental conditions dominated during much of the Late Triassic and in the Early Jurassic and recurred in the Early Cretaceous in the form of basaltic sheets interbedded with coal-bearing deposits.

Folds and faults are most evident as bends and fractures in the hypabyssal sheets. A set of east-west-striking listric normal faults exists on the north coast of Wilczek Land.

Piercement domes and other manifestations of diapirism are observed in the center of Graham Bell Island and on the capes of Wilczek Land.

The major features of the geological structure of the islands are visible in the topography, thus allowing us to study, to a first approximation, the structure of this ice- and water-covered country.

In terms of geomorphology, lithostratigraphy, volcanism, and its germanotype tectonics, Franz Josef Land is similar to East Svalbard and the Sverdrup basin.

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