MESOZOIC STRATIGRAPHY OF FRANZ JOSEF LAND ARCHIPELAGO, ARCTIC RUSSIA - A LITERATURE REVIEW

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ABSTRACT

The Franz Josef Land Archipelago is located on the northeastern edge of the Barents Shelf and includes 132 islands, which cover 16,500 km^2. Upper Triassic to Upper Cretaceous strata outcrop on the islands and are divided into six lithologic units: Upper Triassic shale-siltstone (80 m), Upper Triassic-Lower Jurassic sandstone (800 m), Middle-Upper Jurassic shale-siltstone (450 m), Upper Jurassic-lowermost Cretaceous sandstone (250 m), Lower Cretaceous basalt (500 m), and Upper Cretaceous sandstone (50 m). Well data indicate the occurrence in the subsurface of thick Triassic shales and siltstones (3,000 m), which range in age from Griesbachian to Norian.

The main source area for the Triassic to Jurassic strata was the Ural-Novaya Zemlya foldbelt to the east and south. An uplifted rift shoulder to the north was a likely source area in Late Jurassic and Cretaceous. The widespread Lower Cretaceous basalts probably were related to the Alpha Ridge hot spot.

INTRODUCTION

The Franz Josef Land Archipelago is located on the northeastern edge of the Barents Shelf in the Russian Arctic (Fig.1). The archipelago consists of 132 islands, which vary in size from 2 to over 1,000 km^2. The islands cover an area of about 16,500 km^2 and occur in a roughly rectangular-shaped area, which is about 60,000 km^2. Much of the land area is covered by glacial ice with only about 2,000 km^2 being ice free. The islands tend to have steep sides and relatively flat tops and rise up to 500 m above sea level. The inter-island channels are up to tens of kilometers wide and 400 m deep. The archipelago appears to represent an uplifted plateau that was dissected by now-flooded glacial valleys.

Franz Josef Land was discovered in 1874 by an Austrian-Hungarian expedition. Sporadic geological observations were made by this and subsequent Arctic expeditions in the late 1800's and early 1900's. The most famous of these is the Nansen expedition of 1895-1896. The archipelago became part of the Soviet Union in 1926, and polar bases were established on the archipelago in 1928. Since this time, geological work has been carried out by Russian geologists, and an extensive literature on the surface geology of the area occurs in Russian publications. Subsurface data are available from three deep stratigraphic test wells that were drilled on Franz Josef Land (Fig.1). The stratigraphy of these wells is described in Preobrazhenskaya et al. (1985) and Bro et al. (1989).

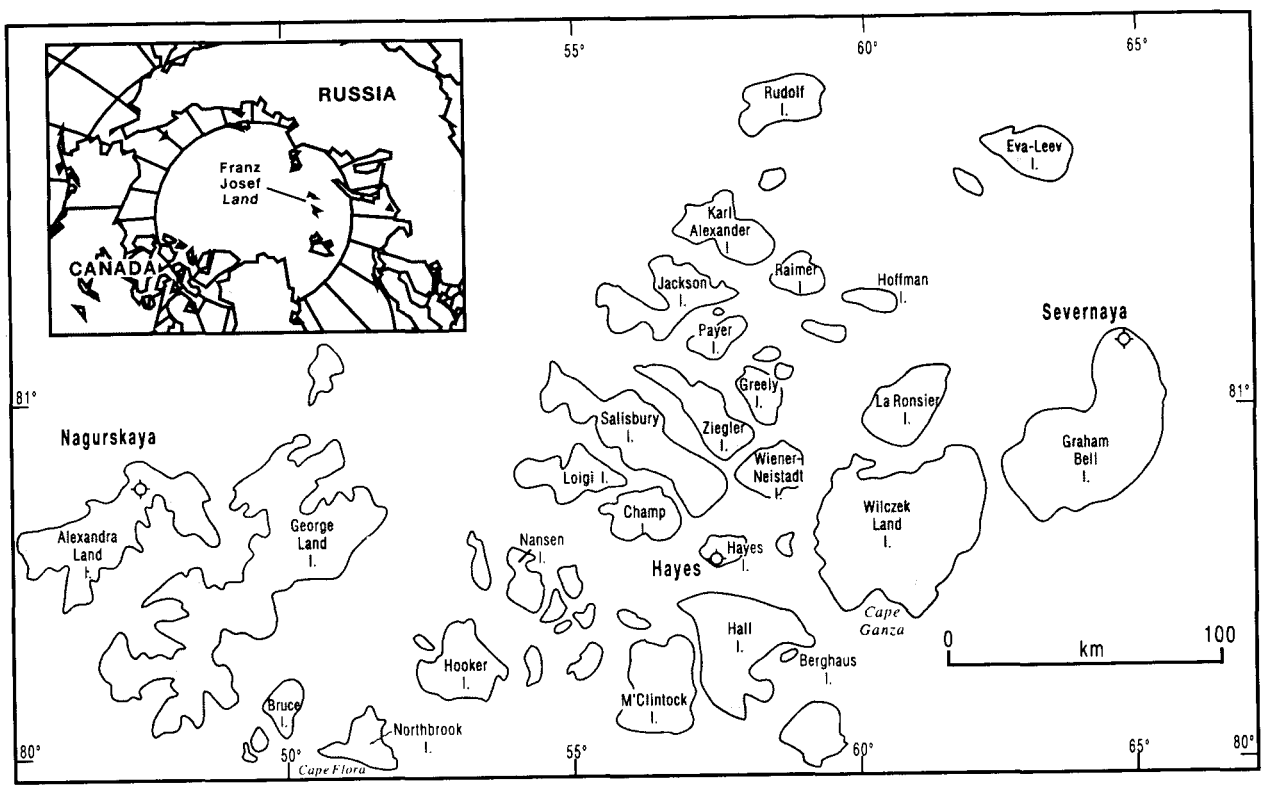

Fig. 1. Geographic map of Franz Josef Land Archipelago with well locations.

This paper is a brief summary of the surface and subsurface Mesozoic stratigraphy of Franz Josef Land and is based mainly on a literature survey of translated Russian publications. This study is part of a joint Canadian-Russian project to compare the stratigraphy and depositional history of the Sverdrup Basin of Arctic Canada with that of the eastern Barents Sea.

SURFACE STRATIGRAPHY

The surface geology of Franz Josef Land has been systematically studied by Russian geologists since 1928. A detailed geological map of the archipelago was first published by V.D. Dibner (1970) and has recently been updated (Dibner, pers. commun., 1992). Six lithologic successions have been mapped throughout the archipelago: (1) Upper Triassic shale-siltstone, (2) Upper Triassic-Lower Jurassic sandstone, (3) Middle-Upper Jurassic shale-siltstone, (4) Upper Jurassic-lowermost Cretaceous sandstone, (5) Lower Cretaceous basalt, and (6) Upper Cretaceous sandstone (Fig.2). All of these units, except the Upper Cretaceous sandstone, are intruded by Cretaceous diabase sills and dykes. The dominant dyke trend is northwest. In general, the strata are gently dipping and are cut by numerous normal faults. The faults trend mainly northwest (parallel to the dykes) and northeast (Dibner, 1957, 1970).

Upper Triassic Shale-Siltstone

This unit represents the oldest outcropping strata on the archipelago and is found at Cape Ganza on southwest Wilczek Land Island (Pirozhnikov, 1958). The strata consist of 9 m of limestone and calcareous siltstone with abundant pelecypods and ammonites overlain by 70 m of dark-grey, silty shale and siltstone with interbeds of very fine-grained sandstone (Fig.2). The basal fossiliferous beds were dated as Carnian by Popov (1958) but recently have been reassigned to the early Norian by Korchinskaya (1985). The strata are offshore marine shelf deposits.

Upper Triassic-Lower Jurassic Sandstone

This is the most widespread map unit on the archipelago and outcrops on all the large islands (Fig.3) except Alexandra Land in the far west. Because the base of the unit is not exposed, the total thickness is difficult to estimate but is likely about 800 m (Dibner and Krilova, 1963) (Fig.3). The unit is unconformably overlain by either Middle Jurassic shales or Lower Cretaceous basalt and sandstone.

Dibner and Sedova (1959) subdivided this thick sandstone-dominant succession into three "suites": Vilchekovskaya, Vasilevskaya, and Tegetkhoffskaya. The Vilchekovskaya is about 250 m thick and is best developed on Wilczek Land Island. The strata consist of very fine- to fine-grained, quartz-rich sandstones with thin interbeds of shale and siltstone. They are of Norian age and are interpreted to represent shallow-marine deltaic deposits.

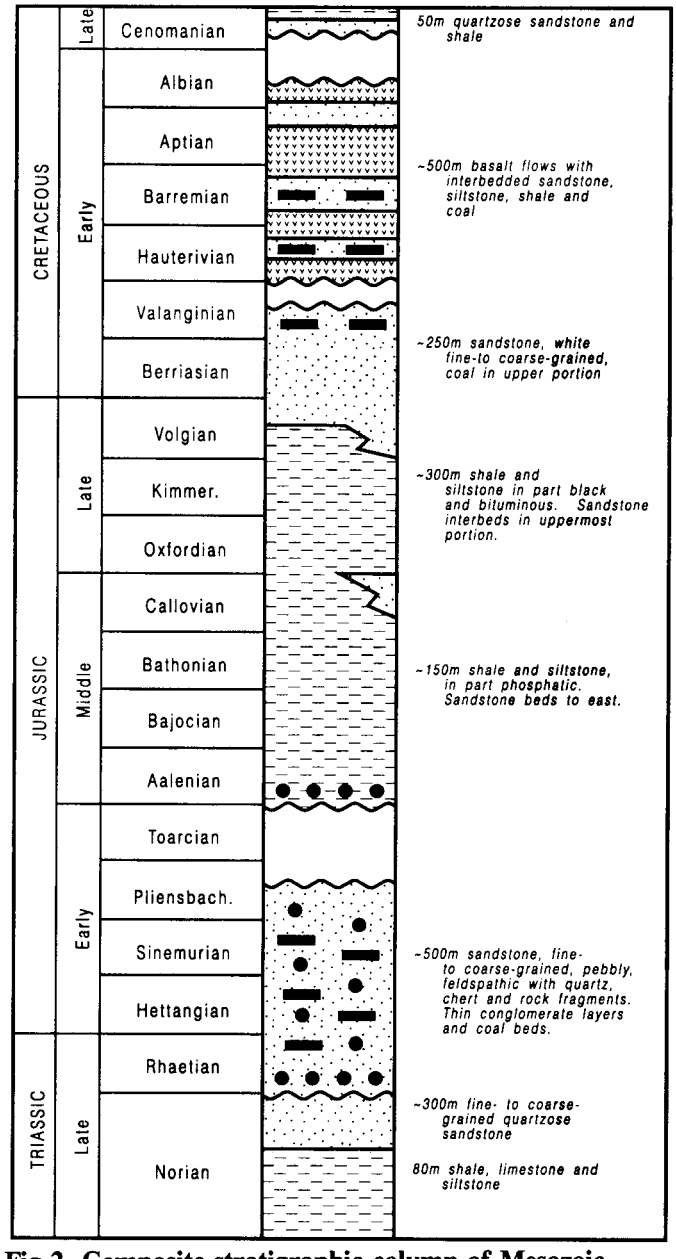

Fig.2. Composite stratigraphic column of Mesozoic surface stratigraphy.

The overlying Vasilevskaya strata are characterized by pebbly, coarse-grained sandstone with thin shale, siltstone, and coal interbeds (Dibner, 1960). Chert is very common in the sandstones, which also contain substantial feldspar. These strata are up to 300 m thick and are dated as Rhaetian by plant remains and palynology (Dibner and Sedova, 1959). They are interpreted to represent mainly delta-plain deposits.

The Tegetkhoffskaya suite consists mainly of quartzose, fine- to medium-grained sandstone with lesser amounts of conglomerate, siltstone, shale, and coal beds. The maximum total thickness is estimated to be 220 m. The strata are dated as Early Jurassic by palynology (Dibner and Sedova, 1959) and are interpreted to be deltaic plain to shallow marine in origin.

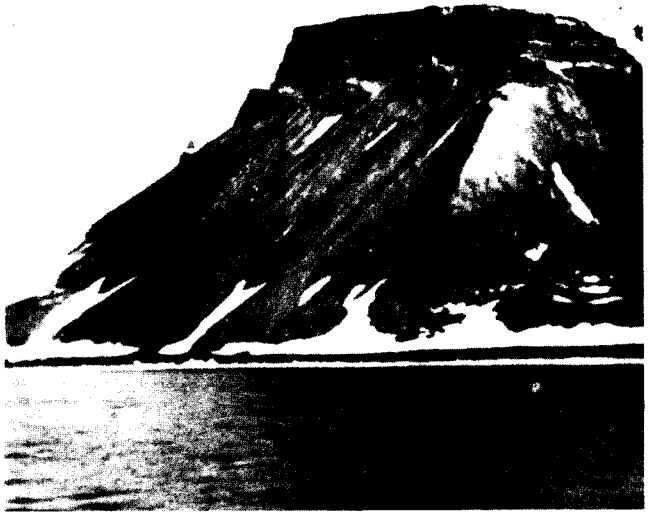

Fig.3. Light weathering Upper Triassic-Lower Jurassic sandstone unit unconformably overlain by Lower Cretaceous basalt unit (dark, resistant cliff), Cape Tirol, Wiener-Neistadt Island.

No regional facies changes in these units have been documented. However, the pebble sizes in both the Vasilevskaya and Tegetkhoffskaya units increase to the southeast (Dibner et al., 1962).

Middle-Upper Jurassic Shale-Siltstone

Strata of this unit have been identified on numerous islands in the southern and eastern portion of the archipelago. They are absent at many localities, especially in the northwest, due to pre-Hauterivian uplift and erosion of much of the archipelago (Fig.3). Where present, the strata unconformably overlie Lower Jurassic sandstones and are commonly unconformably overlain by Lower Cretaceous basalt and sandstone (Fig.2). The strata consist mainly of dark-grey shale and siltstone with minor very fine-grained sandstone. The strata range in age from Aalenian to early Volgian, with the youngest beds found on islands in the southeast. On Champ Island, the strata are 160 m thick but are no younger than Oxfordian (Efremova et al., 1983). Younger Oxfordian, Kimmeridgian, and lower Volgian strata, preserved on Wilczek Land and Berghaus islands, are up to 200 m thick (Shulgina and Mikhailov, 1979). The strata contain abundant ammonites and pelecypods and represent offshore-shelf deposits.

Upper Jurassic-Lowermost Cretaceous Sandstone

These strata occur only on Wilczek Land and Berghaus islands and consist mainly of fine- to coarse-grained sandstone with interbeds of shale, siltstone, and minor coal (Fig.2). Thickness estimates vary from 250 m (Shulgina and Mikhailov, 1979) to 360 m. The strata are dated by ammonites and pelecypods as late Volgian to Valanginian and represent shallow-marine-shelf deposits. The strata are unconformably overlain by the Lower Cretaceous basalt unit.

Lower Cretaceous Basalt

This unit is very widespread throughout the archipelago and lies unconformably on a variety of units ranging in age from Middle Triassic in the northwest (Nagurskaya well) to Lower Cretaceous in the southeast (Fig.3). The unit consists mainly of basalt flows with interbedded units of tuff, sandstone, and carbonaceous shale and siltstone (Dibner 1961, 1978) (Fig.2). Basalt samples collected by Nansen in 1896 recently have been analyzed by Campsie et al. (1988) and Bailey and Brooks (1988). This unit is dated mainly by plant fossils and palynology as Hauterivian to Albian (Dibner, 1961), and the radiometric dates of Tarakhovskay et al. (1983) and Campsie et al. (1988) support this age assignment. The maximum thickness is estimated to be 400 to 500 m. The basalts and interbedded sediments appear to be continental in origin.

Upper Cretaceous Sandstone

The youngest outcropping Mesozoic strata consist of 50 m of quartz sandstone and silty shale with ammonites and pelecypods (Fig.2). These strata are found only on Hoffman Island, and the base and top of the unit are not exposed. The fauna is dated as early Cenomanian (Dibner, 1961).

SUBSURFACE STRATIGRAPHY

Three stratigraphic test wells were drilled on Franz Josef Land, one in the northwest on Alexander Land Island (Nagurskaya), one on the central area on Hayes Island (Hayes), and one in the east on Graham Bell Island (Severnaya) (Fig.1). The stratigraphic sections encountered in these wells are described by Preobrazhenskaya et al. (1985) and Bro et al. (1989) and are briefly summarized here.

The Nagurskaya well (Fig.4) spudded in the Lower Cretaceous basalt unit and drilled 283 m of these strata. The basalt unit unconformably overlies Middle Triassic (Ladinian) dark-grey to black shales and siltstones which are 681 m thick. These beds lie in faulted contact on 693 m of Lower Triassic dark-grey shale and siltstone with a few diabase sills. The Lower Triassic deposits unconformably overlie 83 m of Upper Carboniferous limestone, which in turn unconformably overlie 153 m of Lower Carboniferous sandstones and shales with diabase sills. The basal 1,309 m of the well encountered metamorphic rocks with numerous diabase intrusions. These rocks are interpreted as Precambrian, although a lower Paleozoic age cannot be ruled out.

Both the Hayes and Severnaya wells spudded in the lowermost portion of the Upper Triassic-Lower Jurassic sandstone unit, and they encountered very similar sections that can be readily correlated (Fig.4). A thin Norian shale-siltstone unit (200 m) underlies the sandstones and is equivalent to the oldest outcropping

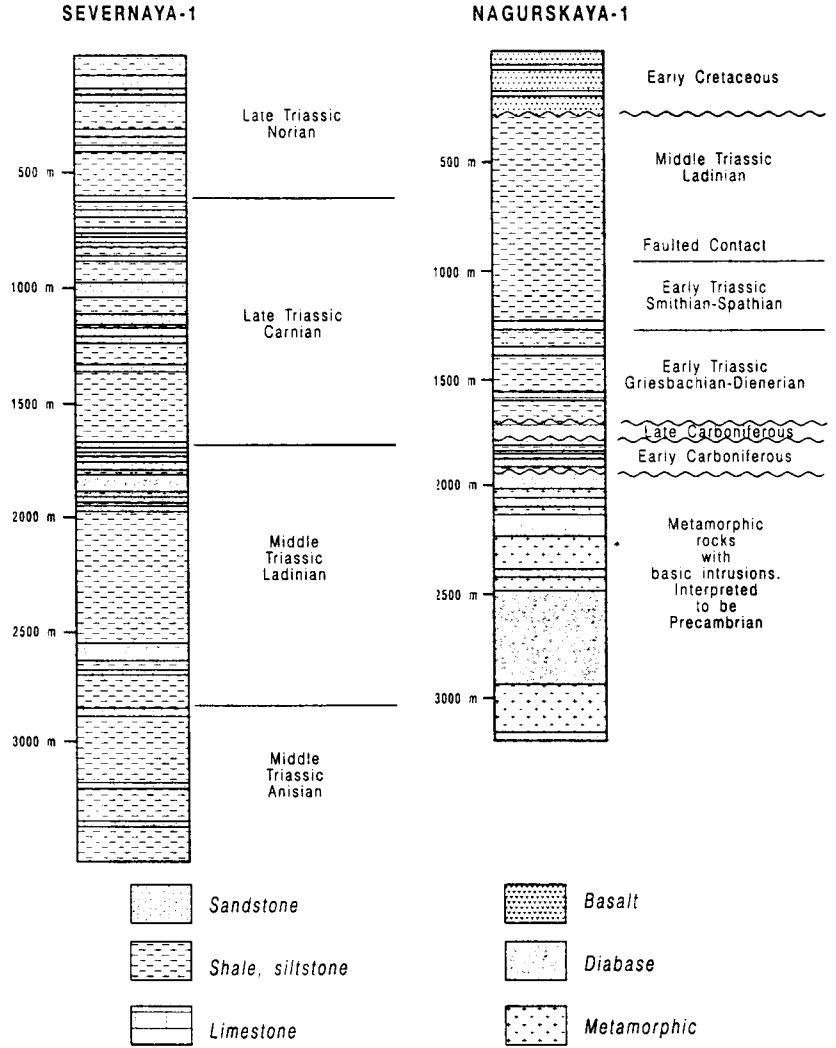

Fig.4. Generalized stratigraphic columns penetrated in the Nagurskaya and Severnaya wells.

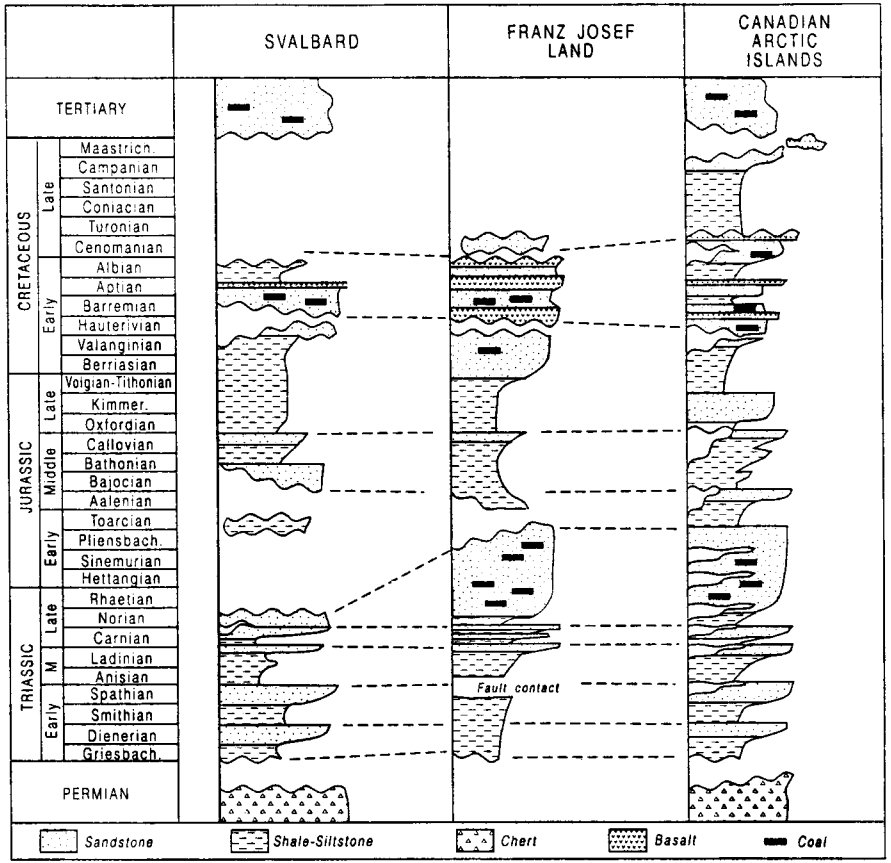

Fig.5. Comparison of Mesozoic stratigraphy of Franz Josef Land with that of Sverdrup Basin of the Canadian Arctic (Embry, 1991) and Svalbard (Steel and Worsley, 1985).

Mesozoic unit. The underlying Carnian strata (1,000 m) consist of grey shale and siltstone in the lower portion with thin, very fine- to fine-grained, burrowed sandstone units interbedded with the shaly lithologies in the upper portion. Ladinian strata (1,000 m) are mainly dark shale and siltstone with interbeds of thin, fine-grained sandstone units in the uppermost portion. Both wells bottom in dark-grey, Anisian shale and siltstone with rare, very fine-grained sandstone interbeds. Four diabase sills were encountered in Severnaya, with seven appearing in Hayes.

In summary, the Lower to Upper Triassic succession which occurs below the Upper Triassic-Lower Jurassic sandstone unit is very argillaceous and consists entirely of offshore-shelf to possibly slope sediments. Of note, the Ladinian strata in the western well contain less siltstone and sandstone than equivalent strata in the eastern wells.

MESOZOIC DEPOSITIONAL HISTORY AND PALEOGEOGRAPHY

From Early Triassic to Norian, the area of Franz Josef Land was an offshore shelf to basin and received only fine sediment. The main source area was likely the uplifted Ural-Novaya Zemlya foldbelt, which shed large volumes of clastics to the northwest during the Permian and Triassic. In support of this interpretation, the Ladinian strata of the area show marked fining from southeast to northwest. Also, there is a possibility that a source area lay to the north of the archipelago at this time, but present data are not sufficient to assess this possibility.

Clastic supply greatly increased in Norian and, by latest Triassic, the area was occupied by a deltaic plain. Again, the main source area of the clastics likely was the foldbelt to the east and south, as evidenced by the increasing pebble size in that direction. Clastic supply remained high in Early Jurassic but greatly decreased in Middle Jurassic when the area was again occupied by an offshore shelf receiving mainly argillaceous sediment. The prime source area at this time is interpreted to have lain to the east because sandstones are more common in eastern sections of Middle Jurassic strata. Clastic supply increased again in latest Jurassic, and the area was eventually occupied by deltaic environments in earliest Cretaceous. The source area of these clastics may have included an uplifted rift shoulder to the north as well as land areas to the east.

The area underwent extensive uplift in Hauterivian and became part of an extensive rift shoulder that bordered the newly formed Amerasia Ocean, which lay to the north. Basaltic volcanism and dyke and sill intrusion, perhaps related to the Alpha Ridge hot spot (Embry and Osadetz, 1988), began following the initial uplift, and the area was part of a widespread basalt plateau from Hauterivian to Albian.

Following cessation of sea-floor spreading in the Amerasia Basin, the area subsided in earliest Late Cretaceous and was part of a shallow-shelf sea in Cenomanian. Later events are unrecorded in the area.

COMPARISON OF FRANZ JOSEF LAND WITH SVALBARD AND SVERDRUP BASIN

As illustrated in Fig.5, the Mesozoic stratigraphy of Franz Josef Land compares closely with that of the Sverdrup Basin of Arctic Canada and Svalbard, which occupies the northwest corner of the Barents Shelf. A major unconformity occurs at the base of the Triassic in all areas, and thick marine shales and siltstones are characteristic of the Griesbachian to Carnian succession. Pronounced transgressions at the base Triassic, base Smithian, base Carnian, and base Norian are recognized in all three areas.

The uppermost Triassic and Lower Jurassic interval of both Franz Josef Land and the Sverdrup Basin contain thick deltaic deposits with numerous coal seams. In contrast, the overlying Middle to Upper Jurassic succession in all three areas consists of relatively thin, marine shale-siltstone strata. A pronounced Hauterivian unconformity punctuates the stratigraphy in the areas, and overlying deposits consist of sandy, deltaic to fluvial deposits with basalt interbeds. Extensive diabase dyke and sill intrusion also occurred in the three areas during the Early Cretaceous. In both the Sverdrup Basin and Franz Josef Land, the Upper Cretaceous strata consist of marine shelf deposits. Overall, it would appear as if the depositional and tectonic history of the three areas has much in common.

CONCLUSIONS

The outcropping Mesozoic strata of Franz Josef Land are up to 2,000 m thick and are subdivided into six lithologic successions: (1) Upper Triassic shale-siltstone, (2) Upper Triassic-Lower Jurassic sandstone, (3) Middle-Upper Jurassic shale-siltstone, (4) Upper Jurassic-lowermost Cretaceous sandstone, (5) Lower Cretaceous basalt, and (6) Upper Cretaceous sandstone. Three major unconformities punctuate the column-base: Middle Jurassic, base Hauterivian, and base Upper Cretaceous.

Three wells have been drilled on the archipelago, and they encountered thick sections (3,000 m) of Lower, Middle, and Upper Triassic dark-grey shale and siltstone with minor sandstone. A major unconformity occurs at the base of the Triassic succession.

The Triassic and Jurassic sediments appear to have been derived mainly from land areas to the east and south. A rift shoulder of the oceanic Amerasia Basin, which lay to the north, likely was uplifted in Late Jurassic and became a prominent source by Early Cretaceous. Throughout much of Early Cretaceous, the area was part of an extensive basaltic plateau related to the Alpha Ridge hot spot.

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