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GEOLOGY OF THE AMOCO IMP SKELLY A-1 OSPREY H-84 WELL, GRAND BANKS, NEWFOUNDLAND

Abstract

Upper Triassic evaporites are now known from the northwest Atlantic. Over 7000 feet of sandstone, mudstones and halite in the Amoco Imp A-1 Osprey H-84 well on the Grand Banks of Newfoundland contain Late Triassic and Early Jurassic palynomorphs. The sequence was deposited in an environment ranging from desert to marginal sabkha. There may have been a possible connection with the Tethys embayment, which developed between the Grand Banks and Iberian Peninsula in the Late Triassic. A marine transgression in the Hettangian-Sinemurian resulted in the deposition of carbonates, which are immediately overlain by marine Upper Cretaceous clastics and marls. The regional geology indicates that deposition occurred in the Jurassic and Lower Cretaceous, the sediments being subsequently removed during uplift of the area in pre-Cenomanian time. The Tertiary sediments are fine grained clastics becoming coarser upwards, and range in age from Eocene to Miocene.

Résumé

On sait maintenant qu'il existe dans le nord-ouest de l'Atlantique des évaporites d'âge triassique supérieur. On a rencontré des palynomorphes d'âge triassique supérieur et jurassique inférieur sur plus de 7000 pieds de grès, mudstone et halite dans le puits Amoco Imp A-1 Osprey H-84 sur les Grands bancs de Terre-Neuve. Cette succession s'est déposée dans un milieu dont le caractère varie entre celui d'un désert et d'une sabkha marginale. Elle a peut-être été en contact avec un embayment de la Téthys, qui se serait formé entre les Grands bancs et la péninsule ibérique au Triassique supérieur. Pendant l'Hettangien et le Sinémurien, une transgression marine a favorisé le dépôt de carbonates, qui ont été immédiatement recouverts par des marnes et des roches clastiques marines d'âge crétacé supérieur. La géologie régionale indique qu'il y a eu sédimentation pendant le Jurassique et le Crétacé inférieur, puis retrait des sédiments lors du soulèvement de cette région avant le Cénomanien. Les sédiments tertiaires sont des roches clastiques à grains fins dont la texture devient plus grossière à mesure qu'on se rapproche de la surface, et dont l'âge se situe entre l'Eocène et le Miocène.

INTRODUCTION

This report describes the lithostratigraphy, biostratigraphy, and depositional history of the Amoco Imp Skelly A-1 Osprey H-84 well (Fig. 1), located in the Carson Basin (Amoco Canada and Imperial Oil, 1973) on the southeastern Grand Banks, approximately 250 statute miles southeast of St. John's, Newfoundland, at 44°43'28.96"N, 49°27'22.92"W. This location is 96 statute miles south of Amoco IOE A-1 Murre G-67 and 47 statute miles east-northeast of Amoco Imp A-1 Jaeger A-49 (Fig. 2). Osprey H-84 was spudded on July 9, 1973, in 201 feet of water and drilled to a total depth of 11 397 feet, with casing set at 455, 797, 2700 and 8001 feet. The well was drilled as a new field wildcat to test a closed anticlinal structure that had been interpreted from seismic data. No significant indications of hydrocarbons were encountered while drilling and no tests were run. The well was abandoned August 16, 1973.

The lithostratigraphy and depositional environment interpretations described below are based on the study of ditch cuttings from 30-foot composite sample intervals, between 11 350 and 830 feet, from the junk basket core taken at the bottom of the well and interpretation of a suite of mechanical logs, including spontaneous potential, resistivity, gamma-ray, and sonic. Sediment composition was studied in 69 thin sections prepared from cuttings, and in smear slides of the poorly consolidated Cretaceous and Tertiary sediments. Although sidewall cores were recovered from the well, no cores were available for the study presented in this report. With the exception of the 25-inch junk basket core, no conventional cores were taken at the well site. The lithostratigraphic units are described in ascending stratigraphic order and are summarized in Table 1.

The biostratigraphy, summarized in Table 2, is based upon the vertical distribution of dinoflagellates and spores in cuttings between 11 290 and 830 feet and of foraminifers and ostracods in cuttings between 3740 and 830 feet. The cuttings are composite samples taken over intervals of 30 feet. Dinoflagellate-spore assemblages also were studied from 51 sidewall cores (of 126 recovered) between 11 350 and 3120 feet and from the junk basket core.

All footages were measured from the rotary table standing 85 feet above sea level and 286 feet above the sea floor.

KETTLE RED BEDS (11 397 – 10 846 ft.)

A terrigenous sequence composed of interbedded reddish mudstone, sandstone and conglomerate underlies the Osprey evaporites and is informally named the Kettle red beds. The canyon, which lies south of the well, has been selected for the unit name.

From 11 397 feet (T.D.) to 11 010 feet there are fine to coarse grained sandstones, which near the base enclose rare granite grains of up to 2 mm in diameter; these are interbedded with siltstones and mudstones. The sandstone is pale red (10R5/4) and forms beds 10 to 40 feet thick, with sharp lower boundaries. Some of the sandstone beds show an upward decrease of the grain size. The quartz grains are subangular to subrounded, frequently coated by iron oxide and moderately sorted. In some of the sandstone beds, up to 20 per cent plagioclase, microcline, and a slightly weathered orthoclase are present. The plagioclase is fresh and near the base of the formation has authigenic overgrowth. Minor components of the sandstone are metaquartzite, acidic gneiss, microcrystalline dolomite grains, muscovite and argillaceous intraclasts. The sandstone is cemented by silica, hematite, sparry calcite and rarely by anhydrite. Some of the voids are filled by euhedral dolomite crystals. The sandstone generally lacks an argillaceous matrix. Anhydrite occurs in traces as void filling. The mudstone forms beds which on the average are less than 15 feet thick. It is variably silty, greyish red (10R5/4), with the argillaceous matter stained by iron oxide.

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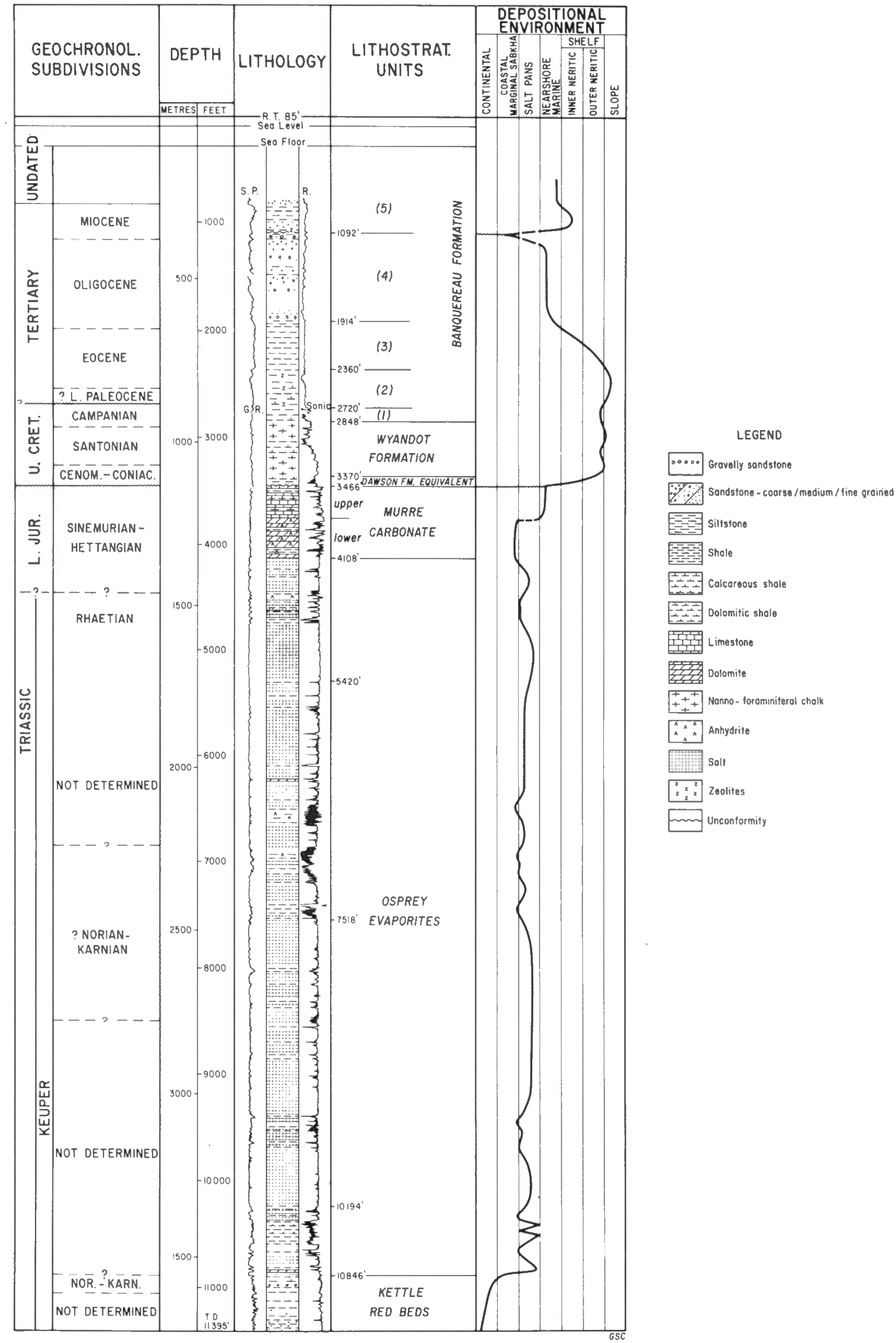

Figure 1. Stratigraphy and depositional environment of Amoco Imp Skelly Osprey H-84, Grand Banks.

From 11 010 to 10 846 feet, strata are dominated by mudstone with rare siltstone beds and minor anhydritic shale. Palynomorphs found in this mudstone indicate a Carnian-Norian age for the upper part of the Kettle red beds.

OSPREY EVAPORITES (10 846 – 4108 ft.)

An evaporite sequence composed of 6738 feet of halite with zones of reddish shale and rare anhydrite, dolomitic mudstone, siltstone and sandstone, here informally named the Osprey evaporites, overlies the Kettle red beds. The boundary between the terrigenous Kettle red beds and the Osprey unit is sharp.

The Osprey evaporites are primarily an Upper Triassic sedimentary sequence and are thus older than the Argo Formation which is of Hettangian-Sinemurian age (Bujak and Williams, in press) and, which in the Shell Eurydice P-36 well of the Scotian Shelf, overlies Rhaetian-Hettangian clastics. The cyclic alternation of halite and shale-halite beds forms the basis for subdivision of the Osprey evaporites into four sub-units:

1. 10 846-10 194 feet – shale-halite sub-unit, comprised of pink halite interbedded with thick reddish and grey coloured dolomitic mudstone beds, rare microcrystalline dolomite and siltstone to fine grained sandstone;
2. 10 194-7518 feet – halite sub-unit, dominated by massive thick bedded coarse crystalline halite, white and pink with rare thin beds and zones of reddish shale;
3. 7518-5230 feet – halite-shale sub-unit, composed of impure, purple halite with thin beds of reddish shale, which are the dominant lithology in the lower half of the sub-unit. Dolomitic mudstone is rare;
4. 5230-4108 feet – halite sub-unit, consisting of thick bedded, clear, coarse crystalline halite with a zone of thin beds of reddish shale, from 4720 to 4430 feet.

Halite, the dominant lithology, in Sub-units 1 and 2 is coarse crystalline, clear or pink, the latter colour resulting from argillaceous impurities. In Sub-unit 3 the halite is always pink and in Sub-unit 4, clear.

The second major lithology is pale red (10R6/2) to greyish red (5R4/2) shale and mudstone, which occasionally has greenish grey reducing spots. Fine silt size grains are scattered in the clayey matrix and on the average do not constitute more than 1 per cent of the sediments. Quartz grains are more common in the shales of the lowest sub-unit. Double-terminated idiomorphic quartz crystals occur sporadically, and occasionally form clusters in Sub-units 2 to 4. Dolomitic shale is rare, light to medium grey (N7 to N5), occurring at 9670, 8730 and 4260 feet, and being common in the lowest sub-unit. The sandstone which sporadically occurs in Sub-unit 1 consists of poorly sorted, subangular quartz grains, up to 10 per cent feldspar (kaolinized orthoclase, plagioclase, and microcline), a variable amount of argillaceous matrix and rare silica cement. Rounding of the quartz grains is most common toward the base of the sub-unit. Leucoxene, rutile, and tourmaline are accessory components, occasionally concentrated in thin laminae. Calcite forms micronodules in the sandstone and dolomite occurs as euhedral isolated crystals in some of the sandstone. The sandstone has no visible porosity.

A basalt fragment found in cuttings from 10 700 to 10 670 feet probably represents caving from the overlying clastic interval (10 660 – 10 600 ft.)

Anhydrite is scattered throughout the Osprey unit but is more common in Sub-units 1 and 4. It forms small pods where the anhydrite has felted and subfelted textures. Traces of argillaceous material are enclosed between anhydrite crystals and also envelop the anhydrite pods indicating that the anhydrite has a nodular form. The anhydrite also forms large, single crystals which are tabular in shape. Grey (N6) microcrystalline dolomite interlaminated with an argillaceous micrite, fine quartz silt peldolomicrosparite and dolomicrosparite occur below 10 194 feet.

The palynologic study indicates a Carnian-Norian age for the interval between 10 880 and 6830 feet (R.E. Dunay, pers. comm.) while a sidewall core at 4497 feet is Rhaetian. The uppermost part of the evaporites is possibly Hettangian. Contact with the overlying Murre unit is sharp.

MURRE CARBONATE (4108 – 3466 ft.)

The sediments from 4108 to 3466 feet are lithologically very similar to the carbonate-evaporite unit informally named the Murre Carbonate by Amoco and Imperial (1973) in the Murre G-67 well. The Murre Carbonate has been correlated with the Iroquois Formation on the Scotian Shelf by Jansa and Wade (1975) and Jansa et al. (1976). New biostratigraphic data suggest that the unit is time-transgressive, and because of uncertainty in the correlation, the name Murre Carbonate is temporarily retained.

The Murre Carbonate in the Murre well was subdivided into three sub-units (Jansa et al., 1976) but only two can be recognized in the Osprey well.

The lower sub-unit (4108-3696 ft.) of the Murre Carbonate consists of a microcrystalline dolomite and anhydrite. The dolomite is pale yellowish brown (10YR6/2) homogeneous, with occasional vugs after leached bioclasts. The microcrystalline dolomite is interbedded with laminated peldolomicrosparite and quartz silty dolomicrosparite and dolointrasparite. Fine, pyrite crystals are scattered in the dolomites and form less than 1 per cent of the rock. Some of the laminated dolomites show low angle cross-lamination and scouring. The irregularly laminated microcrystalline dolomites resemble algal mat laminations. Good intergranular porosity is visible in some of the dolointrasparites and intercrystalline porosity is present in the fine crystalline dolomites.

Anhydrite is common as nodules and may also occur as isolated crystals. In nodules it is white, lath-shaped, and felted and subfelted, sometimes with relicts of a microcrystalline dolomite between anhydrite crystals. The isolated crystals occur either as thin needles or lath-shaped crystals which randomly penetrate the dolomite. Another type of anhydrite which fills some of the fractures in the dolomites is coarsely crystalline. The electric logs indicate that the anhydrite beds may be up to 5 feet thick and are spaced from 10 to 30 feet apart. The thin greyish red (10R4/2) sandy mudstone with rare idiomorphic quartz crystals is intercalated in the dolomite at 4040 and 3860 feet.

In the upper sub-unit (3696-3466 ft.) a microcrystalline dolomite is intercalated with beds of peldolomicrite, peldolosparite and oodolosparite, with peloids and oolites preserved as ghosts. Dolomite is commonly fractured and fractures are healed by sparry calcite. In one bed, dolomitized spiculitic biomicrite, with spicules replaced by silica, was recognized. Several dolomite chips resemble algal mat laminations. Some of the dolomites have good intercrystalline and intergranular porosity (reaching up to 30 per cent). Dedolomitization is locally noticeable, with the microcrystalline dolomite being replaced by coarse sparry calcite.

The uppermost part of the sub-unit (3550-3466 ft.) is greyish orange (10YR7/4), brownish stained, coarse crystalline sparry calcite with a ghost texture of oolitic grainstone and peloid wackestone. The limestone breccia with clasts cemented by coarse sparry calcite is a minor constituent of the uppermost part of the sub-unit. Occasionally occurrences of dense dark grey micrite with clotted fabric relates to the period of the limestone alteration in the vadose zone. Stylolites, calcite-filled veins, and vugs are common.

Table 1

Stratigraphic Table of the Lithologic Units in the Amoco Imp Skelly Osprey H-84

Formation/Unit	Depth Interval (ft)	Dominant Lithology	Depositional Environment	Age
Banquereau				
Unit 5	1092 – 825	sand-mudstone	shallow marine, high energy periods	Miocene
----------				?hiatus
Unit 4	1914 – 1092	sand	marginal marine with period of subaerial emergence at top of the unit	Early Miocene Oligocene-
Unit 3	2360 – 1914	mudstone, glauconitic		Late Eocene
Unit 2	2720 – 2360	zeolitic clay-mudstone-siltstone	deep, outer shelf to upper slope, slow deposition	Early-middle Eocene
----------				?hiatus
Unit 1	2848 – 2720	nannofossil-bearing mudstone	shallowing upward	Campanian
Wyandot	3370 – 2848	nannofossil-bearing marlstone-calcareous shale	deep outer shelf	Early Campanian Coniacian-
Dawson Canyon equivalent	3466 – 3370	shale-siltstone	open marine, shallow shelf	Coniacian Cenomanian-
----------		unconformity		
Murre Carbonate	4108 – 3466	Limestone-dolomite, anhydrite	shallow marine to tidal flats	Sinemurian Hettangian-
Osprey evaporites	10 846 – 4108	halite-minor reddish shale and anhydrite	desert lake and marginal sabkha?	Early Jurassic Late Triassic-
Kettle red beds	(T.D.) 11 397 – 10 846	sandstone-reddish mudstone and rare conglomerate	desert	Late Triassic

The Murre Carbonate is strongly influenced by secondary limestone alteration, related to the diagenetic changes at the unconformity. Palynological evidence indicates a Hettangian-Sinemurian age for the carbonates. The younger Jurassic strata were removed by erosion, when the southeastern portion of the Grand Banks was subaerially exposed in late Early Cretaceous time (Jansa and Wade, 1975).

DAWSON CANYON FORMATION EQUIVALENT (3466 – 3370 ft.)

Fine terrigenous clastics of Cenomanian-Coniacian age unconformably overlie the Lower Jurassic carbonates. The basal silt represents the first marine sediment deposited over the unconformity. It is composed of moderately sorted, rounded to subangular quartz, 15 per cent grassy green glauconite, rare orthoclase, muscovite, phosphatic and mollusc fragments. The mollusc fragments are worn and cemented by microsparite. The siltstone grades upward into light olive-grey (5Y6/1) calcareous mudstone, which is interbedded with thin calcareous siltstone and skeletal sandy limestone beds. The limestone is composed of a mixture of echinoderm debris, unidentifiable skeletal grains, glauconite, variable amounts of quartz grains and rare pyrite, all cemented by sparry calcite. Several anhydrite crystals were noted in the micritic matrix of the calcareous siltstone.

Because of the similarity in lithologic composition, stratigraphic position and the age, this unit is considered to correlate with the Dawson Canyon Formation defined on the Scotian Shelf (McIver, 1972) and subsequently recognized on the southern Grand Banks (Jansa and Wade, 1975). Contact with the overlying Wyandot Formation is transitional.

WYANDOT FORMATION (3370 – 2848 ft.)

The Wyandot Formation in Osprey H-84 is composed of nannofossil marlstone with intercalations of calcareous shale and siltstone, and is subdivided into three sub-units. The lower sub-unit (3370-3082 ft.) is a light grey (N8) soft marlstone to highly argillaceous chalk with nannofossils, planktic foraminifers and **Inoceramus** fragments dispersed throughout the micrite and clayey matrix. The middle sub-unit is a zone of light grey calcareous shale (3082-3012 ft.). The upper sub-unit, a light grey marlstone, is similar in composition to the marlstone of the lower sub-unit. The marlstone is composed of a mixture of clay and micrite and 10 to 60 per cent of nannofossils. Coccospheres are relatively common, as are planktic foraminifers. Occasional **Inoceramus** prisms occur throughout.

The interval 3370 to 2848 feet has been dated Santonian-Early Campanian. Since this agrees favourably with the age and lithology of the Wyandot Formation as defined for the Scotian Shelf by McIver (1972), the nannofossil-bearing marlstone-chalk is assigned to this formation. The boundary with the overlying formation is transitional.

BANQUEREAU FORMATION (2848 – ?825 ft.)

The Upper Cretaceous-Tertiary mudstone and sand sequences are included in the Banquereau Formation, erected by McIver (1972) for coeval sediments on the Scotian Shelf. Hardy (1975) subsequently subdivided the Banquereau Formation into four units. Even though some of the units in the Osprey well are of similar lithology to units recognized on the Scotian Shelf, Hardy's stratigraphic nomenclature is not applied, because of uncertainty concerning the ages of her units. Five distinct lithologic units can be recognized in the Osprey well.

The lowest lithological unit (1) of the Banquereau Formation is a light grey (N7) nannofossil-bearing calcareous mudstone (2848-2720 ft.) with rare planktic foraminifers (5 per cent in a smear slide), and is similar to the underlying Wyandot Formation.

According to the biostratigraphic data, the interval 2840 to 2720 feet is Campanian and 2660 to 2630 feet is early Eocene age. There is a change in lithology at 2720 feet, which is probably associated with a hiatus but poor sample control precludes resolution of the situation. Alternatively, the missing sample interval of 60 feet from 2720 to 2660 feet, which has not been examined for microfossils or lithology, may span all of Maastrichtian-Paleocene time, and represent a condensed sequence.

The strata from 2720 to 2360 feet is a light grey (N8) zeolitic calcareous clay mixed with a homogeneous dark yellowish brown (10YR6/2, 10YR4/2) sandy glauconitic mudstone (with local occurrence of up to 60 per cent of glauconite) and unconsolidated sand beds (Unit 2). The zeolites increase in abundance upwards; their occurrence is taken to indicate very slow pelagic deposition. Planktic foraminifers (up to 10 per cent) and nannofossils (up to 50 per cent) vary in abundance in the smear slides. Radiolaria tests are occasionally present. The SP and resistivity mechanical logs indicate a thick argillaceous sand and thin silt beds in the interval 2470 to 2360 feet which was not sampled.

This sequence is overlain by a homogeneous mudstone (Unit 3) which extends from 2360 to 1914 feet. The mudstone is dark yellowish brown (10YR6/2, 10YR4/2), sandy glauconitic. Glauconite grains comprise about 3 per cent of the mudstone. Additional constituents are rare nannofossils, foraminifers, mollusc fragments, and muscovite. The sequence from 2720 to 1914 feet (Units 2 and 3) is Eocene to early Oligocene. There is a gradational contact with the overlying sandy sequence.

Unit 4 (1914-1092 ft.) is dominantly a sandy sequence composed of loose quartz grains with a few thin mudstone intercalations. The average thickness of the sand beds is 40 feet, with some of the composite sand units being up to 190 feet thick. The interbedded mudstone is less than 10 feet thick.

The lower interval (1914-1690 ft.) is a brownish grey (5YR4/1), fine grained, argillaceous, micaceous, glauconitic sandstone to sandy mudstone. The glauconite grains are grassy green and constitute 10 per cent of the sample. Fragments of mollusc shells, gastropods and foraminifers are rare. The sand is coarse grained to conglomeratic with predominantly clear, moderately rounded and sorted quartz, with stained quartz increasing in relative abundance up to 1470 feet. Above this footage the quartz grains are yellowish brown stained, polished, well sorted and rounded. The sand contains up to 20 per cent dark brown botryoidal glauconite, rare chert fragments and pyrite, with the latter occasionally cementing the quartz grains. The light olive-grey (5Y6/1) mudstone, found interbedded with the sand, encloses rare nannofossils and glauconite. If the mudstone is not caved then it would indicate a marginal marine origin for the sand. The coarsest sand bed occurs at the top of the unit (1155-1110 ft.). Unit 4 is Oligocene to Miocene in age. Contact with the overlying Unit 5 is sharp.

The uppermost lithologic unit (Unit 5, 1092-825 ft.) has at the base a light grey and yellowish brown, calcareous, glauconitic mudstone. The glauconite is botryoidal and oxidized, which may indicate the presence of a lacuna at the base of the unit. The coarse fragments of thick-walled molluscs are whitish with a chalky surface. The mudstone grades upwards into a 76-foot-thick bed of quartz sand (1080-1004 ft.), consisting of coarse, highly polished, well sorted and rounded grains, which are pitted. The additional sand component is about 7 per cent of mollusc shell fragments and rare glauconite grains. The sand grades into 100-foot-thick medium yellowish brown mudstone (10YR5/4) which contains rare nannofossils, radiolaria and sponge spicules. The mudstone is interbedded with several approximately 10-foot-thick sand beds.

The uppermost bed examined in the well is a 40-foot-thick sand unit composed of loose quartz grains, rare glauconite, mollusc fragments and traces of bryozoans. The quartz grains are frosted, well rounded and sorted, with some probably representing caved material.

Samples in the uppermost part of the well are of poor quality and are probably not representative of the indigenous sediment composition, due to washing out of the fine fraction with subsequent concentration of the coarse sand. The unit is (late) Miocene in age.

Table 2

Summary of Chronostratigraphy in Amoco Imp Skelly Osprey H-84

The Upper Cretaceous and Lower Tertiary succession is condensed, but because sample intervals are relatively broad the boundaries of geochronological units can only be placed to the nearest hundred feet.

Footage (ft)	Age
1310 – 830	Miocene
------------- 1365 hiatus -------------	
1670 – 1370	(Late) Oligocene
1940 – 1640	Early Oligocene
2390 – 2000	Late Eocene
2450	Middle Eocene
2660 – 2540	Early Eocene
-------------- hiatus --------------	
2750 – 2720	Late Campanian
2840 – 2810	Early Campanian
3290 – 2900	Santonian
3350 – 3380	Coniacian
3470 – 3440	Cenomanian and Turonian
3466 -----------unconformity-----------	
4435 – 3530	Hettangian-Sinemurian
4497	Rhaetian
6830 – 4500	not determined
8510 – 6830	Carnian-Norian
10 850 – 8510	not determined
10 880 – 10 850	Carnian-Norian
11 060 – 10 880	not determined
11 090 – 11 060	Carnian-Norian
11 390 – 11 095	not determined
11 397 – 11 395	??

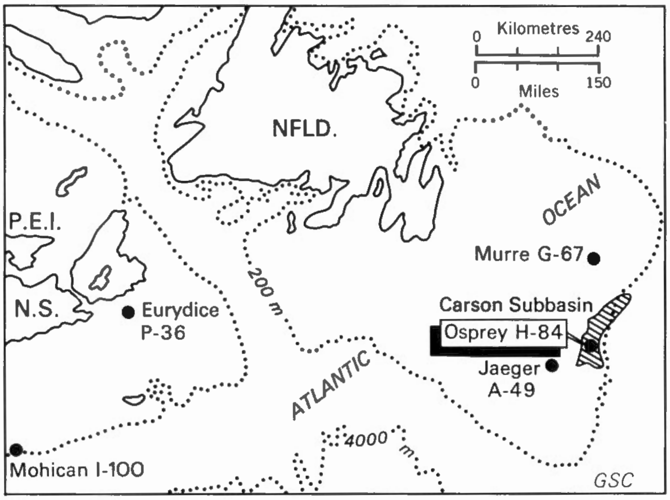

Figure 2. Location map.

BIOSTRATIGRAPHY

SPORES AND DINOFLAGELLATES

Palynological analyses of the interval 11 397 to 830 feet in Amoco Imp Skelly Osprey H-84 revealed the presence of Upper Triassic, Lower Jurassic, Upper Cretaceous and Tertiary rocks. The youngest sediments dated are late Miocene. Middle and Upper Jurassic, Lower Cretaceous, Maastrichtian and Paleocene strata appear to be absent.

The proportion of terrigenous (spores) to marine (dinoflagellates) organic microfossils varies according to the age of the sediments. Exclusively terrigenous assemblages occur in the Upper Triassic (11 090-4497 ft.) and Lower Jurassic (?4435-3530 ft.) whereas mixed assemblages with a predominance of dinoflagellates are present in Upper Cretaceous (3470-2720 ft.) and Tertiary (2660-830 ft.) strata. The Upper Triassic and Lower Jurassic strata are dated by spores. The Upper Cretaceous and Tertiary strata are dated using the dinoflagellate-spore zonation proposed by Williams (1975).

Zones and Assemblages

Porcellispora longdonensis Assemblage (Carnian-Norian) (11 090 – 6830 ft.)

The impoverished assemblage includes **Porcellispora longdonensis** (Clarke) Scheuring which is known from the Upper Keuper of England (Clarke, 1965). Geiger and Hopping (1968) noted its abundance in the Late Triassic which comprises the Carnian, Norian and Rhaetian. They do, however, state that its "top occurrence" would appear to delineate the Norian-Rhaetian boundary. Morbey and Neves (1974) recorded **P. longdonensis** only from their TR Zone which is of ?Norian-earliest Rhaetian age. However, Bujak and Williams (in press) noted **P. longdonensis** in probable Rhaetian Sinemurian sediments from the Scotian Shelf. These authors erected a **Corollina meyeriana** Peak Zone which they dated Rhaetian-Hettangian. The absence of **C. meyeriana** in the interval 11 090 to 6830 feet in contrast to the overlying strata in Osprey H-84 suggests that it may be Carnian-Norian in age. Other taxa present are **Enzonalasporites** sp. and **?Ovalipollis** sp.

Corollina meyeriana Peak Zone (4497 ft.)

A sidewall core at 4497 feet contains abundant specimens of **Corollina meyeriana** (Klaus) Venkatachala and Góczan and **Corollina torosus** (Reissinger) Klaus is absent. Bujak and Williams (in press) erected a **Corollina meyeriana** Peak Zone in the Scotian Shelf well Shell Eurydice P-36, which is dominated by this species and which they date as Rhaetian, possibly in part Hettangian.

Corollina torosus Assemblage (Hettangian-Sinemurian) (?4435 – 3530 ft.)

Several horizons within this interval contain abundant specimens of **Corollina torosus** as well as **Corollina simplex** (Danzé-Corsin and Laveine). Bujak and Williams (in press) include such assemblages in their **Cycadopites subgranulosus** Assemblage Zone, recognized in Shell Argo F-38, Eurydice P-36, and Mohican I-100 on the Scotian Shelf, which is dated Hettangian-Sinemurian. Although **C. torosus** has a known range of Rhaetian-Turonian on the Scotian Shelf-Grand Banks (Williams, 1975; Bujak and Williams, in press), it is found as a dominant species only in Early Jurassic assemblages.

Cleistosphaeridium polypes Zone (Cenomanian) (3470 ft.)

The single sidewall core sample included in the Cenomanian contains the age diagnostic dinocysts **Cleistosphaeridium huguonioti** (Valensi) Davey, **Epelidosphaeridium spinosa** (Cookson and Hughes) Davey, **Litosphaeridium siphoniphorum** (Cookson and Eisenack) Davey and Williams, and **Palaeohystrichophora infusorioides** Deflandre. Davey (1969, 1970) and Williams (1975) have discussed the ranges of these species which overlap only in the Cenomanian. As noted earlier, the **Cleistosphaeridium polypes** Zone and the subsequent Late Cretaceous and Tertiary zones are after Williams (1975).

Turonian-Coniacian (3370 ft.)

Species present include **Hystrichokolpoma ferox** (Deflandre) Davey, and **Kleithriasphaeridium loffrense** Davey and Verdier. Reworked Lower Cretaceous spores are common.

Santonian-Campanian (3320 – 2720 ft.)

Species not extending into younger sediments include **Chatangiella tripartita** (Cookson and Eisenack) Lentin and Williams, **Dinogymnium undulosum** Cookson and Eisenack, **Odontochitina costata** Alberti, **Palaeohystrichophora infusorioides** Deflandre, and **Xenascus ceratioides** (Deflandre) Lentin and Williams. Such an assemblage is characteristic for Santonian-Campanian sediments of offshore eastern Canada (Williams, 1975). Between 2720 feet and 2660 to 2630 feet, where there is an early Eocene dinocyst assemblage, there is no sample coverage. However, **Deflandrea speciosa** Alberti, a Late Paleocene zonal index species, and **Extratriporopollenites** sp. are present in the interval 2750 to 2720 feet. This suports the presence of Paleocene sediments between 2720 and 2660 feet. It is possible that there is no hiatus between the Campanian and lower Eocene rocks, but rather a condensed sequence. Also caved but lower down in the cuttings sample from 3020 to 2990 feet is **Membranilarnacia ursulae** Morgenroth. This has a restricted stratigraphic range of late Early Eocene to Middle Eocene.

Areoligera senonensis Zone (early Eocene) (2660 – 2630 ft.)

The rich dinocyst assemblage includes the age diagnostic species **Adnatosphaeridium reticulense** (Pastiels) de Coninck sensu Gocht, 1969, **Cordosphaeridium gracile** (Eisenack) Davey and Williams, **Deflandrea leptodermata** Cookson and Eisenack, **Muratodinium fimbriatum** (Cookson and Eisenack) Drugg, and **Wetzeliella homomorpha** Deflandre and Cookson. This is taken to indicate an early Eocene age for this interval (Williams, 1975).

Early-middle Eocene (2570 – 2450 ft.)

The presence of the dinocyst taxa, **Deflandrea wetzeli** Morgenroth, **Rhombodinium condylos** (Williams and Downie) Lentin and Williams, **Rhombodinium** cf. **condylos** and **Wetzeliella ovalis** Eisenack, indicates an early to middle Eocene age. **Deflandrea wetzeli** was described originally from the Early Eocene of northern Germany by Morgenroth (1966) and **Rhombodinium condylos** is known only from the Early Eocene of southern England (Costa and Downie, 1976). **Rhombodinium** cf. **condylos** is present throughout the Eocene of the Grand Banks. The presence of **Deflandrea wetzeli** and **Rhombodinium condylos** suggests an early Eocene age, but since the foraminifers indicate a middle Eocene age at 2450 feet, it is possible that some or all of the interval is middle Eocene. The interval 2390 to 2090 feet contains no palynomorphs so that the presence of Upper Eocene sediments cannot be proven.

Deflandrea heterophlycta Zone (early Oligocene) (1940-1460 ft.)

Rich and diverse dinocyst assemblages are recovered from the interval 1940 to 1460 feet which is included in the **Deflandrea heterophlycta** Zone of Williams (1975). Species present include **Deflandrea heterophlycta** Deflandre and Cookson, **D. phosphoritica** Eisenack, **D. spinulosa** Alberti, **Kisselevia coleothrypta** (Williams and Downie) Lentin and Williams, and **Tubidermodinium sulcatum** Morgenroth. The assemblages are similar to those recorded by Williams (1975) from the early Oligocene of the Scotian Shelf and Grand Banks.

Chiropteridium dispersum Zone (Oligocene) (1400 – 1190 ft.)

The recovery of dinocysts from this interval and in younger sediments in Osprey H-84 is extremely poor. However, the presence of **Chiropteridium dispersum,** which is known only from the Oligocene (Williams, 1975) strongly suggests an Oligocene age.

Apteodinium sp. B Zone (early Miocene) (1130 – 1100 ft.)

The sparse assemblage includes the zonal index species, **Apteodinium** sp. B as well as **Operculodinium centrocarpum** (Deflandre and Cookson) Wall, and **Systematophora ancyrea** Cookson and Eisenack.

Pentadinium laticinctum Zone (middle Miocene) (1040-1010 ft.)

The assignment of the interval 1040 to 1010 feet to the **Pentadinium laticinctum** Zone is based on the presence of the species **Maduradinium spatiosum** (Morgenroth) Lentin and Williams.

Cannosphaeropsis sp. A Zone (late Miocene) (860 – 830 ft.)

Species in this interval include the dinocyst **Lingulodinium machaerophorum** (Deflandre and Cookson) Wall and the spores **Alnipollenites verus** (Potonié) ex Potonié, and **Osmundacidites** sp. The last named does not extend above the late Miocene in other wells on the Scotian Shelf and Grand Banks; the 860 to 830 feet interval is therefore dated late Miocene.

FORAMINIFERS

The cuttings samples from the Osprey H-84 well between 3470 and 1190 feet contain many benthic and planktic foraminifers. Below 3470 feet and also between 1190 feet and the uppermost sample at 830 feet, samples are barren of shelly microfossils. Specimens of **Gavelinopsis cenomanica** at 3620 feet are interpreted as caving from a thin Cenomanian interval above the Triassic-Jurassic nonmarine sediments occurring immediately below 3466 feet.

From 3466 to 2720 feet there are diversified, abundant assemblages of Late Cretaceous planktic and benthic foraminifers. The former include large Globotruncanids. Samples at 2630, 2540 and 2450 feet are from an Eocene mudstone with abundant planktics and a few, mostly arenaceous, benthics. From 2360 to 1190 feet the slides contain a low diversity benthic fauna with some specimens of planktics (i.e. **Globigerina).**

Ostracods are uncommon between 3466 and 2700 feet. From 2630 to 2450 feet there are frequent radiolarians; coral, bryozoan and mollusc fragments are common in the interval from 2360 to 1820 feet.

The foraminiferal biostratigraphy of the Osprey H-84 sediments is based on the stratigraphically highest occurrence of taxa, which permit recognition of six 'assemblages' and six zones. The assemblages are informal units which have stratigraphic significance on the Grand Banks. The Tertiary assemblages are also recognized on the Labrador Shelf and have been discussed in detail by Gradstein and Williams (1976). The Late Cretaceous zones follow Postuma (1971); the Eocene zones are of Stainforth et al., (1975). Some of the Late Cretaceous zones tentatively are also expressed in van Hinte's (1976) numerical zone designation. Assemblages and zones are listed in ascending stratigraphic order (see Table 1); species listed do not occur stratigraphically higher. Plates 1-3 illustrate diagnostic taxa. Specimens illustrated are stored in the GSC collections, nos. 53716 – 53751.

Gavelinopsis cenomanica Assemblage (Cenomanian) (approximately 3465 ft.)

The specimens of **Gavelinopsis cenomanica** Brotzen (Plate 1, fig. 8) at 3800 and 3620 feet are interpreted as caved from a thin Cenomanian interval above the unconformity at 3466 feet.

Globotruncana helvetica Zone (Turonian) (3440 ft.)

The few specimens of planktics include **Globotruncana primitiva** Dalbiez, **G. renzi** Gandolfi (Plate 1, figs. 9, 10), **G. schneegansi** Sigal, and **Praeglobotruncana stephani** Gandolfi (Plate 1, fig. 11). The assemblage correlates with Postuma's (1971) **Globotruncana helvetica** Zone and with an abundance of planktic foraminifers in the Amoco IOE Murre G-67 well and in the Amoco Imp Skelly Egret K-36 well, Grand Banks (Jansa et al., 1976; Gradstein et al., 1976).

Globotruncana schneegansi-G. concavata Zones (Coniacian-early Santonian) (3350 ft.)

Globotruncana concavata (Brotzen) (Plate 1, figs. 6, 7), **G. renzi** Gandolfi, **G. cretacea** (d'Orbigny), **G. marginata** (Reuss), **G.** aff. **schneegansi Gublerina (Sigalia) deflaensis** (Sigal) (Plate 1, fig. 5), **Hedbergella bosquensis** Pessagno, **H. amabilis** Loeblich and Tappan are present in this zone. The assemblage correlates with Zones UC6-UC8 of van Hinte (1976).

Globotruncana carinata Zone (late Santonian) (3260-2900 ft.)

Planktics include **Globotruncana carinata** Dalbiez (Plate 1, figs. 1, 2), **G. coronata** Bolli (Plate 2, figs. 11, 12), **G. cretacea** (d'Orbigny), **G.** ex. gr. **linneiana** (d'Orbigny), **G. marginata** (Reuss), **G. angusticarinata** Gandolfi (Plate 2, figs. 9, 10) **Gublerina (Sigalia) deflaensis** (Sigal), **Gaudryina austinana** Cushman (Plate 1, fig. 4), and **G. stephensoni** Cushman (Plate 1, fig. 3). Coarse grained, large agglutinated foraminifers are also present. Ostracods, Grand Banks spp. 3, 36, 37 and 39 were recognized, proving correlation with the Santonian in the Amoco IOE Eider M-75, Grand Banks (Gradstein, 1976).

The presence of **Sigalia** and the absence of **Globotruncana concavata** indicates correlation with the lower part of van Hinte's (1976) **G. elevata** Zone (lower UC9) of late Santonian age. This interval in Osprey H-84 is remarkable in the frequency of **G. carinata** which appears to be rare to common in many other Grand Banks wells. It is possible that this frequency is due to the fact that the Osprey site was relatively far from shore during the late Santonian.

Globotruncana elevata Zone (early Campanian) (2810 ft.)

Globotruncana angusticarinata Gandolfi, **G. conica** White, **G. cretacea** (d'Orbigny), **G. elevata** (Brotzen)-**G. stuartiformis** Dalbiez (Plate 2, figs. 7, 8), **G. fornicata** Plummer, **G.** ex. gr. **linneiana** (d'Orbigny), **G. ventricosa** White, **G. carinata** Dalbiez (one fragment), **Gaudryina** sp. 2, **Planulina taylorensis** (Carsey) (Plate 2, figs. 5, 6) and ostracod species No. 2 and 37 occur in this single sample.

Planulina taylorensis Assemblage (late Campanian) (2720 ft.)

Species include **Globotruncana arca** Cushman, **G. fornicata** Plummer, **G.** aff. **stuartiformis** Dalbiez, **G.** ex. gr. **linneiana** (d'Orbigny), **Globorotalites multiseptus** (Brotzen), **G. michelinianus** (d'Orbigny), **Arenobulimina americana** Cushman, **Planulina taylorensis** (Carsey), **Stensioina pommerana** Brotzen, and **S. exculpta** (Reuss). **Planulina taylorensis** is particularly common and morphologically well developed.

Globorotalia subbotinae Zone (early part of Early Eocene) (2660-2540 ft.)

The assemblages contain many planktic foraminifers including **Globigerina linaperta** Finlay, **G. soldadoensis** (Bronniman), **G. primitiva** (Finlay), **Globorotalia aequa** Cushman and Renz (Plate 2, figs. 1,2), **G. aragonensis** (Nuttall) (Plate 2, figs. 3,4), **G. subbotinae** Morozova (Plate 3, figs. 11, 12), **G.** aff. **broedermanni** Cushman and Bermudez. Benthics include **Gaudryina** sp. 10 and **Gavelinella** spp. Diatoms and radiolarians are common.

Hantkenina aragonensis-Globorotalia lehneri Zones (early part of Middle Eocene) (2450 ft.)

The planktics **Globorotalia bulbrooki** Bolli Group (Plate 3, fig. 9) , **G. spinulosa** Cushman (Plate 3, fig. 10), **G. densa** (Subbotina), **Truncorotaloides** aff. **rohri** Bronniman and Bermudez, are present together with **Gaudryina** sp. 10, and **Marginulina decorata** (Reuss) s.l., diatoms and radiolarians.

At 2520 feet the lithology changes from a calcareous interval below to a more terrigenous clastic interval above. This is reflected in the preservation of tests. Specimens of **Marginulina decorata,** according to their preservation, may be caved from the overlying **Pteropod** sp. 1 assemblage in which it is common (Gradstein and Williams, 1976).

Pteropod sp. 1 Assemblage (middle-late Eocene) (2360-2000 ft.)

The contained fauna includes **Globigerina linaperta** Finlay, **G.** aff. **yeguaensis** Weinzierl and Applin, **G. venezuelana** Hedberg (Plate 3, fig. 5), **Catapsydrax** cf. **dissimilis** (Cushman and Bermudez) (Plate 3, fig. 7), **Globigerinatheka index** (Finlay) (Plate 3, fig. 6), nodosariids (including **Nodosaria** sp. 8), **Pteropod** sp. 1 (Plate 3, figs. 3, 4), bryozoans, corals, and gastropods.

Pteropod sp. 1 on the Grand Banks and Labrador Shelf seems to be more common and more widespread than **Globorotalia centralis** Cushman and Bermudez, which commonly occurs in the same samples. The latter species is present in Osprey H-84 only in the underlying zone at 2540 feet. Because of its translucent shell at that depth it contrasts markedly with the other planktic shells which are all coated whitish due to a more limy lithology. As such it may well be caved from the **Pteropod** sp. 1 interval where shells are more translucent in preservation.

?Oligocene (1910-1820 ft.)

Samples at 1910 and 1820 feet contain **Globigerina venezuelana** Hedberg, **Uvigerina dumblei** Cushman and Applin, **Cyclogyra involvens** (Reuss), nodosariids, coral fragments and molluscs. **Uvigerina dumblei** also occurs in the Amoco Imp Skelly Egret K-36 well, Grand Banks, in the Oligocene-Miocene **Spiroplectammina carinata** assemblage (Gradstein et al., 1976). It has also been observed in the Scotian Shelf well, Shell Triumph P-50, where it ranges from Oligocene (with **Globorotalia opima opima**) to Middle Miocene (with **Globorotalia fohsi** group). It was originally described from Eocene strata.

In the absence of stratigraphically more restricted species the Oligocene age cannot be confirmed. **Turrilina alsatica,** which is indicative of Grand Banks and Labrador Shelf Oligocene beds (Gradstein and Williams, 1976), has not been recorded from Osprey H-84.

Spiroplectammina carinata Assemblage (Oligocene-Miocene) (1640-1370 ft.)

Foraminifers include **Ceratobulimina contraria** (Reuss), **Spiroplectammina carinata** (d'Orbigny) (Plate 3, fig. 2), **Gyroidina girardana** (Reuss), **Nonion affine** (Reuss), **Globigerina praebulloides** Blow s.l., and **Asterigerina gurichi** (Francke) s.l. (?cavings).

Asterigerina gurichi Assemblage (Miocene) (1280-1190 ft.)

The species **Asterigerina gurichi** (Francke) s.l., **Asterigerina** sp. 2 and **Globigerina bulloides** d'Orbigny are present in the interval 1280 to 1190 feet.

From 1100 to 830 feet, washed residues are devoid of foraminifers and only contain few mollusc fragments and glauconite which testify to a shallow neritic paleoenvironment.

DEPOSITIONAL ENVIRONMENT

Kettle red beds (T.D. 11 397-10 846 ft.) (late Triassic)

The presence of an impoverished spore assemblage and the absence of marine fossils suggests a nonmarine environment. This is confirmed by the terrigenous sequence of sandstone, reddish mudstone, and rare conglomerates, which indicate deposition under terrestrial-desert conditions.

Osprey Evaporites (10 846-4108 ft.) (predominately late Triassic)

The only microfossils are rare spores. The dominant lithology is massive halite with minor reddish shale and anhydrite. The environment is interpreted as hypersaline semirestricted marginal marine(?).

Murre Carbonate (4108-3466 ft.) (Hettangian-Sinemurian)

The sediments in this interval consist of limestone, dolomite and anhydrite, very similar to the carbonate evaporite unit in the Murre G-67 well, Grand Banks, where it was interpreted to have formed under semirestricted lagoonal and tidal flats to inner neritic conditions (Jansa et al., 1976). In Osprey H-84 the Murre Unit contains numerous spores but no marine microfossils.

Dawson Canyon Equivalent (3466-3370 ft.) (Cenomanian-Coniacian)

This interval is a glauconitic shale-siltstone sequence with spores, dinoflagellates and rare to common planktic and rare benthic foraminifers. The sediments were deposited in an open marine, relatively shallow, shelf environment. The absence of Cenomanian planktic foraminifers and their increase in the Senonian is taken to reflect a gradual deepening of the sea.

Table 3

Foraminiferal stratigraphy in Amoco Imp Skelly Osprey H-84, Grand Banks; Cretaceous zones follow Postuma (1971), Eocene zones are after Stainforth et al. (1975)

PLANKTICS	BENTHICS	AGE	
	Asterigerina gurichi *	Miocene	Tertiary
	Spiroplectammina carinata *	Oligocene-Miocene	Tertiary
	indeterminate	?Oligocene	Tertiary
Pteropod sp. 1 *		middle-late Eocene	Tertiary
Globorotalia lehneri **Hantkenina aragonensis**		early Middle Eocene	Tertiary
Globorotalia subbotinae		early Early Eocene	Tertiary
Planulina taylorensis *		late Campanian	Late Cretaceous
Globotruncana elevata		early Campanian	Late Cretaceous
Globotruncana carinata		late Santonian	Late Cretaceous
Globotruncana concavata **Globotruncana schneegansi**		Coniacian-early Santonian	Late Cretaceous
Globotruncana helvetica		Turonian	Late Cretaceous
Gavelinopsis cenomanica *		approximately Cenomanian	Late Cretaceous

* – Canadian Atlantic margin assemblages (for the Tertiary see also Gradstein & Williams, 1976).

Wyandot Formation (3370-2848 ft.)
(Coniacian/Santonian-early Campanian)

This is a nannofossil-bearing marlstone, argillaceous chalk, and calcareous shale sequence in Osprey H-84. The washed residue contains abundant stoutly built **Globotruncanid** planktic foraminifers, including several single keeled forms. Hedbergellids and **Heterohelix** are relatively small and less common. The environment is interpreted as deep neritic to ?epibathyal (upper slope), relatively far from shore.

Banquereau Formation (2848-825 ft.)
(late Campanian-Miocene)

The lowest units of the Banquereau Formation consist of nannofossil-bearing calcareous mudstone and zeolitic clay-mudstone-siltstone of late Campanian and Eocene age. The Upper Campanian beds contain fewer planktic foraminifers than the underlying interval, possibly because of a slight regressive trend. However, the washed residue from the lower-middle Eocene strata contain abundant planktic foraminifers (many Globorotalids) and also radiolarians together with some benthics, including **Gavelinella danica, Dorothia**-like forms, **Cibicidoides** spp. and **Bulimina**. This presumably indicates a transgressive pulse with deposition in a deep neritic (outer shelf) to bathyal (upper slope) environment. A lacuna or a highly condensed sequence separates the Cretaceous and Tertiary strata.

During Late Eocene-Oligocene time, rapid shallowing may have occurred which would account for the change to a low diversity foraminiferal assemblage with bryozoans, corals, and gastropods.

The interval 1914 to 1092 feet is predominantly sandy with some mudstone intercalations. It contains relatively few foraminiferal taxa, with almost no pelagics (only **Globigerina**). The benthics include **Giroidina Cyclogyra, Spiroplectammina,** and **Nonion affine.** At 1820 feet frequent costate **Uvigerina** occur; molluscs are common. The upper samples have a foraminiferal assemblage which is almost monotypic, consisting essentially of **Asterigerina** spp. There are none of the benthic taxa which characterize the middle Tertiary of southwestern Grand Banks wells such as Amoco IOE Puffin P-90 (Jenkins et al., 1974). Those include **Cyclammina** spp. and many other coarse arenaceous species, **Melonis pompilioides, Uvigerina rustica,** and stilostomellids, interpreted as of deep marine, slope character. The mid-Tertiary environment at Osprey was shallow neritic with high energy periods.

The uppermost lithologic sub-unit between 1092 and 825 ft. of Miocene age is a sand-mudstone sequence with some glauconite, rare molluscs, nannofossils, radiolarians and sponge-spicules. The environment was very shallow marine, with high energy periods.

HYDROCARBON OCCURRENCE

No indications of oil stain were observed in cuttings of the Osprey well. The Triassic and lower Jurassic rocks lack porosity. High porosity is present in unconsolidated Tertiary sand beds, but no hydrocarbon accumulation was encountered in the Osprey well.

CONCLUSIONS

The Amoco Imp Skelly A-1 Osprey H-84, drilled in the Carson Basin, penetrated Upper Triassic, Lower Jurassic, Upper Cretaceous, and Tertiary sediments. The only microfossils in the more than 7000 feet of Upper Triassic-Lower Jurassic strata are spores and pollen, which are interpreted as being predominantly nonmarine. The Kettle red beds, of Late Triassic age, include sandstones and mudstones deposited in a desert environment. The overlying Upper Triassic-Lower Jurassic Osprey evaporites are mostly halite deposited in a marginal sabkha environment and shallow hypersaline basin. The dominance of halite, with only minor dolomite and lack of bedded anhydrite, indicate that the Osprey evaporites were deposited from relatively saline brines, already depleted of less soluble calcium and magnesium carbonates and sulphates. This suggests that the basin was interconnected to another evaporitic basin, probably located east to northeast of the Carson Basin, and connected to the Lusitanian Basin or to the westward continuation of the Aquitaine Basin. A second interpretation is that the Carson and Lusitanian basins were marginal basins to the Tethys embayment which had developed between the Grand Banks and Iberian Peninsula in early-Late Triassic time.

A Hettangian-Sinemurian marine transgression is reflected by the Murre Carbonate, a limestone-dolomite, deposited in a shallow water shelf environment. Regional geology indicates deposition probably continued throughout the Jurassic and into the Cretaceous with subsequent removal of these sediments as a result of the uplifting of the area in pre-Cenomanian time. Consequently, Cenomanian sediments directly overlie the Murre Carbonates in the Osprey H-84 well.

A major transgression occurred in the Cenomanian with progressive deepening throughout the Late Cretaceous. Basal clastics grade upwards into nannofossil marlstones correlatable with the Wyandot Formation of the Scotian Shelf. Either nondeposition or a highly condensed sequence separates Campanian from Lower Eocene strata. Deposition in the Early and Middle Eocene was slow as indicated by zeolitic clays, with water depths probably corresponding to the outer shelf to upper slope. From Late Eocene to Miocene time there was progressive shallowing with fine-grained clastics grading into sandy sequences in the Miocene, the environment being high energy shallow marine.

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REFERENCES

Amoco Canada Petroleum Company Ltd. and Imperial Oil Limited
1973: Regional geology of the Grand Banks; Bull. Can. Pet. Geol., v. 21, p. 479-503.

Bujak, J.P. and Williams, G.L.
Jurassic palynostratigraphy of offshore eastern Canada; Elsevier publication of Symposium, "Stratigraphic Micropaleontology of the Atlantic Basin and Borderlands." (in press).

Clarke, R.F.A.
1965: Keuper miospores from Worcestershire, England; Palaeontology, v. 8, p. 294-321.

Costa, L.I. and Downie, Charles
1976: The distribution of the dinoflagellate **Wetzeliella** in the Palaeogene of northwestern Europe; Palaeontology, v. 19, p. 591-614.

Davey, R.J.
1969: Non-calcareous microplankton from the Cenomanian of England, northern France and North America, Part I; Bull. Br. Mus. Nat. Hist. (Geol.), v. 17, p. 103-180.

1970: Non-calcareous microplankton from the Cenomanian of England, northern France and North America, Part II; Bull. Br. Mus. Nat. Hist. (Geol.), v. 18, p. 333-397.

Geiger, M.E. and Hopping, C.A.
1968: Triassic stratigraphy of the southern North Sea Basin; Phil. Trans. Roy. Soc., ser. B, v. 254, p. 1-36.

Gradstein, F.M.
1976: Biostratigraphy (Foraminifera) and depositional environment of Amoco IOE Eider M-75, Grand Banks of Newfoundland; Geol. Surv. Can., Open File 334, 17 p.

Gradstein, F.M., Jenkins, W.A.M., and Williams, G.L.
1976: Biostratigraphy and depositional history of Amoco Imp Skelly B-1 Egret K-36, Grand Banks of Newfoundland; Geol. Surv. Can., Open File 396, 9 p.

Gradstein, F.M. and Williams, G.L.
1976: Biostratigraphy of the Labrador Shelf, Part 1; Geol. Surv. Can., Open File 349, 39 p.

Hardy, I.A.
1975: Lithostratigraphy of the Banquereau Formation of the Scotian Shelf; Geol. Surv. Can., Paper 74-30, v. 2, p. 163-174.

Jansa, L.F., Gradstein, F.M., Harris, I.M., Jenkins, W.A.M., and Williams, G.L.
1976: Stratigraphy of the Amoco IOE Murre G-67 well, Grand Banks of Newfoundland; Geol. Surv. Can., Paper 75-30, 14 p.

Jansa, L.F. and Wade, J.A.
1975: Geology of the continental margin off Nova Scotia and Newfoundland; Geol. Surv. Can., Paper 74-30, v. 2, p. 51-105.

Jenkins, W.A.M., Ascoli, P., Gradstein, F.M., Jansa, L.F. and Williams, G.L.
1974: Stratigraphy of the Amoco IOE A-1 Puffin B-90 well, Grand Banks of Newfoundland; Geol. Surv. Can., Paper 74-61, 12 p.

McIver, N.L.
1972: Cenozoic and Mesozoic stratigraphy of the Nova Scotia Shelf; Can. J. Earth Sci., v. 9, no. 1, p. 54-70.

Morbey, S.J. and Neves, R.
1974: A scheme of palynologically defined concurrent-range zones and subzones for the Triassic Rhaetian Stage (sensu lato); Rev. Palaeobot. Palynol., v. 17, p. 161-173.

Morgenroth, Peter
1966: Mikrofossilien und Konkretionen des nordwesteuropäischen Untereozäns; Palaeontographica, Abt. B, v. 119, p. 1-53.

Postuma, J.A.
1971: Manual of planktonic foraminifera; Elsevier Publishing Co., Amsterdam.

Stainforth, R.M., Lamb, J.L., Luterbacher, H., Beard, J.H., and Jeffords, R.M.
1975: Cenozoic planktonic foraminiferal zonation and characteristics of index forms; Univ. of Kansas, Pal. Contrib., Art. 62 (incl.) Appendix, 425 p., 2 figs.

van Hinte, J.E.
1976: A Cretaceous time scale; Bull. Am. Assoc. Pet. Geol., v. 60, no. 4, p. 498-516, fig. 1-9.

Williams, G.L.
1975: Dinoflagellate and spore stratigraphy of the Mesozoic-Cenozoic, offshore eastern Canada; Geol. Surv. Can., Paper 74-30, v. 2, p. 107-161.

PLATES

PLATE 1

Upper Cretaceous

Figure 1. **Globotruncana carinata** Dalbiez, cts 2990' (x 130).
2. **Globotruncana carinata** Dalbiez, cts 2990' (x 130).
3. **Gaudryina stephensoni** Cushman, cts 2910' (x 115).
4. **Gaudryina austinana** Cushman, cts 2810' (x 115).
5. **Gublerina (Sigalia) deflaensis** (Sigal), cts 3170' (x 220)
6. **Globotruncana concavata** (Brotzen), cts 3350' (x 165).
7. **Globotruncana concavata** (Brotzen), cts 3350' (x 165).
8. **Gavelinopsis cenomanica** Brotzen, cts 3620' (x 220).
9. **Globotruncana renzi** Gandolfi, cts 3350' (x 140).
10. **Globotruncana renzi** Gandolfi, cts 3350' (x 140).
11. **Praeglobotruncana stephani** Gandolfi, cts 3440' (x 175).

PLATE I

PLATE 2

Upper Cretaceous and Lower Tertiary (Eocene)

Figure 1. **Globorotalia aequa** Cushman and Renz, cts 2630' (x 200).

2. **Globorotalia aequa** Cushman and Renz, cts 2630' (x 200).

3. **Globorotalia aragonensis** (Nuttall), cts 2630' (x 200).

4. **Globorotalia aragonensis** (Nuttall), cts 2630' (x 200).

5. **Planulina taylorensis** (Carsey), cts 2720' (x 105).

6. **Planulina taylorensis** (Carsey), cts 2720' (x 105).

7. **Globotruncana elevata** (Brotzen)-**stuartiformis** Dalbiez, cts 2720' (x 120).

8. **Globotruncana elevata** (Brotzen)-**stuartformis** Dalbiez, cts 2720' (x 120).

9. **Globotruncana angusticarinata** Gandolfi, cts 2810' (x 130).

10. **Globotruncana angusticarinata** Gandolfi, cts 2810' (x 130).

11. **Globotruncana coronata** Bolli, cts 2990' (x 120).

12. **Globotruncana coronata** Bolli, cts 2990' (x 120).

PLATE 2

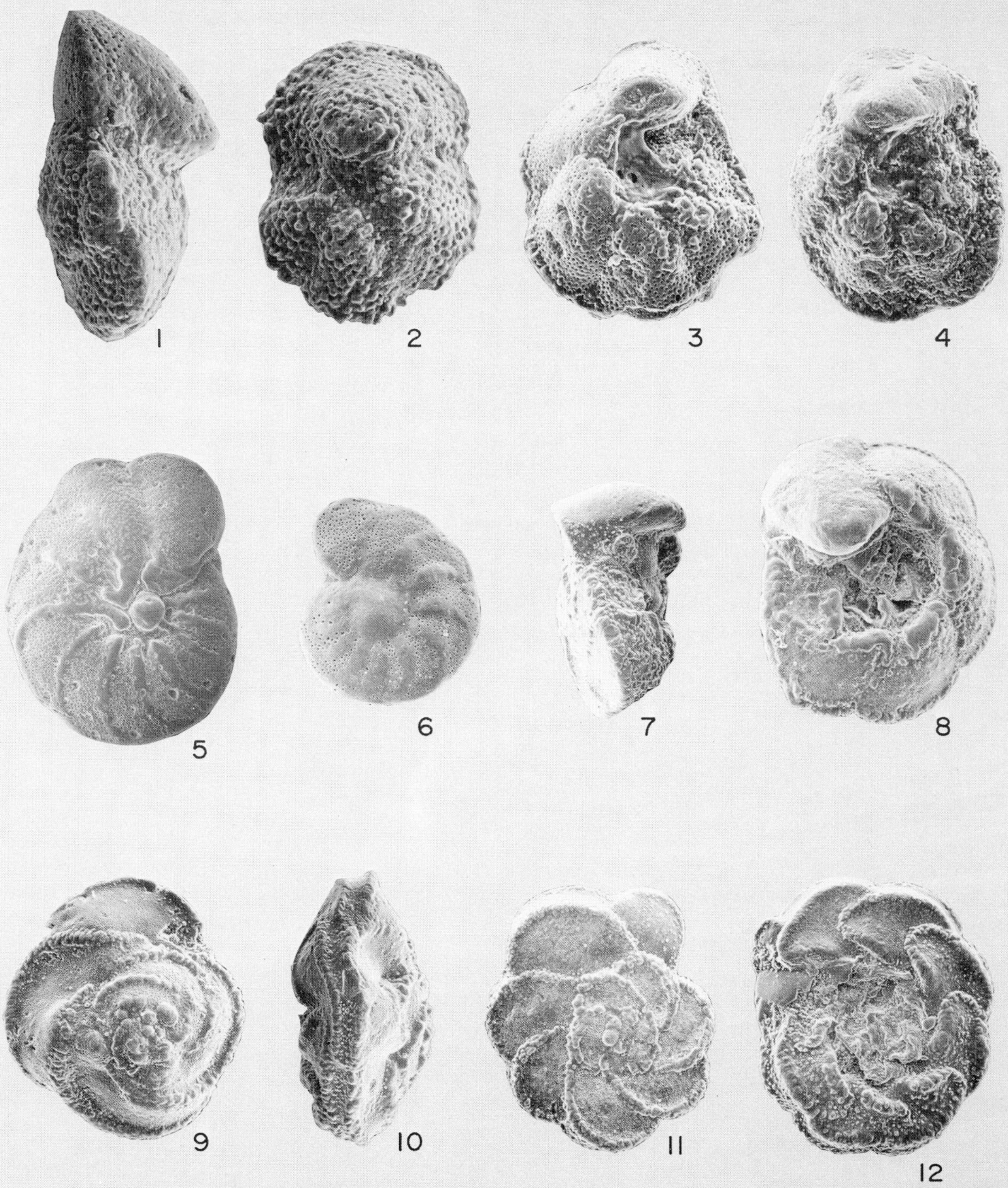

PLATE 3

Tertiary (Eocene-Miocene)

Figure 1. **Asterigerina gurichi** (Francke), cts 1190' (x 240). (Sutures and chamberlets have been drawn in.)

2. **Spiroplectammina carinata** (d'Orbigny), cts 1640' (x 240).

3. **Pteropod** sp. 1, cts 2270' (x 200).

4. **Pteropod** sp. 1, cts 2270' (x 200).

5. **Globigerina venezuelana** Hedberg, cts 2260' (x 200).

6. **Globigerinatheka** index (Finlay), cts 2360' (x 275).

7. **Catapsydrax** cf. **dissimilis** Weinzierl and Applin, cts 2360' (x 450).

8. **Globigerina linaperta** Finlay, cts 2450' (x 350).

9. **Globorotalia** ex gr. **bulbrooki** Bolli, cts 2450' (x 320).

10. **Globorotalia spinulosa** Cushman, cts 2450' (x 270).

11. **Globorotalia subbotinae** Morozova, cts 2630' (x 230).

12. **Globorotalia subbotinae** Morozova, cts 2630' (x 230).

PLATE 3