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N.C. MEIJER DREES

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Abstract

The upper part of the Bear Rock, the Funeral and the lower part of the Hume Formations are described using information obtained from a study of the cores of the Candex et al. Dahadinni M-43A well. Paleontological and stratigraphic evidence suggests that these formations range from ?Lower to Middle Devonian.

The Bear Rock Formation and the basal part of the Funeral Formation are sequential deposits. The complete sedimentary succession includes, in ascending order, beds of subtidal, intertidal and supratidal environments. The contacts between the sedimentary sequences is sharp and each is commonly overlain by a thin pebble bed.

The Evaporitic member of the Bear Rock Formation includes sequences of laminated dolostone which grade upward into nodular anhydrite or bedded anhydritic rocks. In the Dolomitic member of the Bear Rock Formation the sequences consist of laminated limestone that grades upward to dolostone. In the basal part of the Funeral Formation argillaceous beds grade upward to limestone.

The upward change in the lithology of the Bear Rock and Funeral Formations is correlated with a postulated change in environment from offshore and nearshore positions to an onshore position. The interbedded succession of limestone, argillaceous limestone and marl in the upper part of the Funeral and lower part of the Hume Formation may represent a shallow-water and semi-restricted marine environment.

An erosional surface below a thin limestone pebble bed is present in the basal part of the Hume Formation. It represents a hiatus or local unconformity.

In the Dahadinni well, the lower part of the Hume Formation and the upper part of the Funeral Formation are duplicated by a fault. The presence of several fractured zones and steeply to vertical dipping intervals in the Bear Rock Formation and the anomalously thick section of the Evaporitic member in the well suggest that the lower part of the Bear Rock Formation is repeated by folding or faulting.

Porosity is present in some dolostone beds that occur interbedded with the anhydrite. Some brecciated intervals are also porous. The porous beds were not tested in the well but are believed to be water bearing.

Résumé

Dans le présent rapport, on décrit la tranche supérieure de la formation de Bear Rock, la formation de Funeral, et la tranche inférieure de la formation de Hume, en utilisant l'information fournie par une étude des carottes de sondage du puits Candex et al. Dahadinni M-43A. Les indices paléontologiques et stratigraphiques suggèrent que l'âge de ces formations se situe entre le Dévonien inférieur et le Dévonien moyen.

Des observations sédimentologiques et lithologiques détaillées indiquent que la tranche supérieure de la formation de Bear Rock et la partie basale de la formation de Funeral, réprésentent une succession de dépôts régressive, qui comprennent, de bas en haut, des lits de milieux subtidaux, intertidaux et supratidaux. Dans la formation de Bear Rock, le membre évaporitique est constitué de roches composées de dolomite et d'anhydrite; le membre dolomitique comprend des couches alternées de dolomitite et de calcaire. La partie basale de la formation de Gossage est formée de calcaires et de quelques couches de dolomitite. Les modifications verticales de la lithologie, de bas en haut, sont sans doute liées à des modifications du milieu, en particulier à un recul du rivage. Les successions alternées de calcaires, calcaires argileux, et marnes dans la tranche supérieure de la formation de Funeral, et dans la tranche inférieure de la formation de Hume indiquent un milieu marin peu profond, plus ou moins clos.

Une surface d'érosion sous-jacente à un mince lit de galets apparaît dans la partie basale de la formation de Hume, et représente une lacune ou une discordance locale.

Dans la formation de Bear Rock, certains lits de dolomitite, interstratifiés avec l'anhydrite, présentent un certain degré de porosité. Certaines zones poreuses constituées de brèches de fort pendage ont été décelées dans les carottes de sondage; on a pu démontrer que des failles provoquent la répétition de la partie inférieure de la formation de Hume.

DESCRIPTION OF THE HUME, FUNERAL AND BEAR ROCK FORMATIONS IN THE CANDEX ET AL. DAHADINNI M-43A WELL, DISTRICT OF MACKENZIE

INTRODUCTION

The Candex et al. Dahadinni M-43A well (Lat. 63°52'59.3"N, Long. 124°39'15.1"W) is located in the southern part of the Mackenzie Plain (see Fig. 1) and was drilled in 1971 to evaluate the hydrocarbon potential of the Devonian, Ordovician and Cambrian strata present in the subsurface. The well was drilled to a depth of 3708 feet (1130.2 m) and, from there down, the Devonian succession was cored to a depth of 10 272 feet (3130.9 m). At that point, the well was abandoned for geological and mechanical reasons. The cores were packed and handled with care and form an excellent reference section in which the sedimentological features of the ?Lower to Middle Devonian carbonates and evaporites can be studied in detail.

Previous work

Many geologists have studied the Lower to Middle Devonian succession from outcrop sections in the Franklin and Mackenzie Mountains in the northern parts of Western Canada. During Operation Mackenzie in 1957, the Geological Survey of Canada investigated the southern part of District Mackenzie and the results have been published by Douglas and Norris (1960, 1961, and 1963). The discovery of gas in the Beaver River and Pointed Mountain Anticlines in the Liard River area in 1963 and 1967 intensified the exploration for oil and gas in the southern Mackenzie Mountains. The Middle Devonian carbonates received special attention because they form the reservoirs at Pointed Mountain and Beaver River. A number of oil company exploration reports are on file with the Department of Indian and Northern Affairs and the reports by Brady and Wissner (1961) and Capstick (1968) were most useful.

In the northern part of the Mackenzie and Franklin Mountains, the Middle Devonian strata have been studied since oil was discovered in Norman Wells in 1920. During the Canol Project, the geology of the area was investigated in some detail. Hume (1954) has summarized the geological investigations that took place between 1921 and 1954.

The Devonian stratigraphy and biostratigraphy of the area is relatively well established (see Basset, 1961) and the reader is referred to Tassonyi (1969) and Law (1971). Recently, Gabrielse et al. (1973), Aitken and Cook (1974), and Williams (1975) have added to the general knowledge of the Devonian stratigraphy in the study area.

Present work

In this report, the Middle Devonian succession in the subsurface of the Dahadinni M-43A well between the depths of 3708 and 10 272 feet (1130.2-3130.9 m) is described in some detail from available cores. A total of 2629 feet (801.3 m) of core was described in detail.

The stratigraphical subdivision used is a mixture of terms introduced by Tassonyi (1969), Bassett (1961) and Douglas and Norris (1961, 1963). The lower part of the Hume Formation, the Funeral Formation and the upper part of the Bear Rock Formation are described. Based on the data obtained, subsurface correlation of these rock units with equivalent units in the Mackenzie Mountains is established (Fig. 2) and an interpretation of the environment of deposition for each unit is presented.

The terms used to describe the carbonate and sulphate rocks are based on the classification of Dunham (1962) as modified by Embry and Klovan (1971, Fig. 2). Nodular recrystallized anhydrite is named according to the classification proposed by Maiklem et al. (1969).

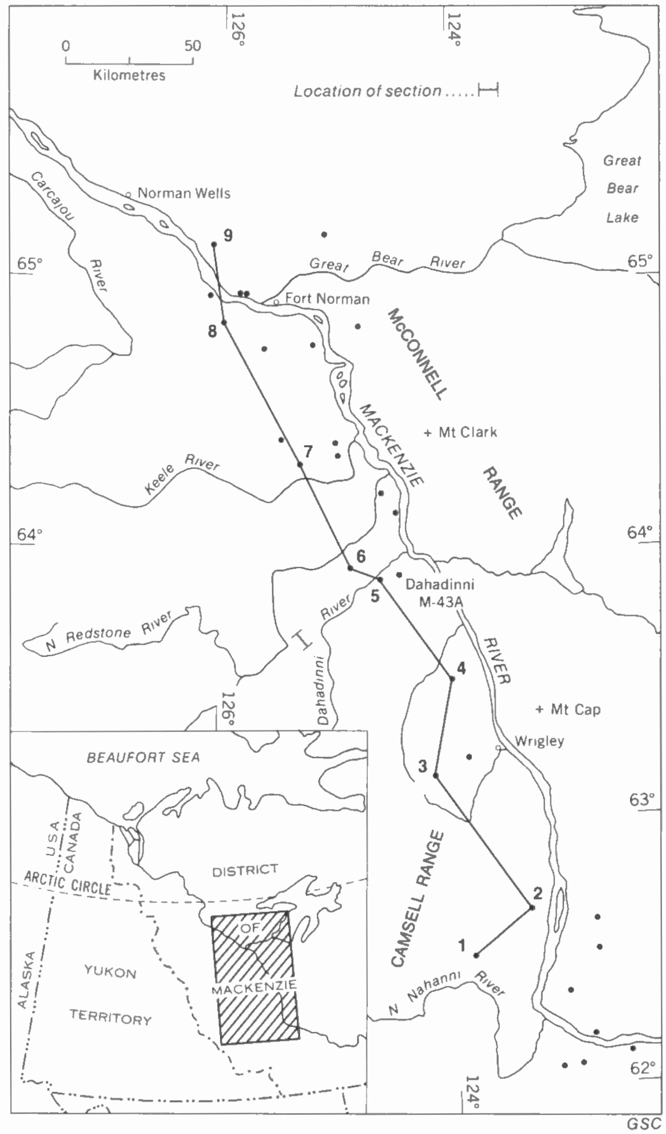


FIGURE 1. Map showing the location of the Dahadinni M-43A well and the cross-section on Figure 3.

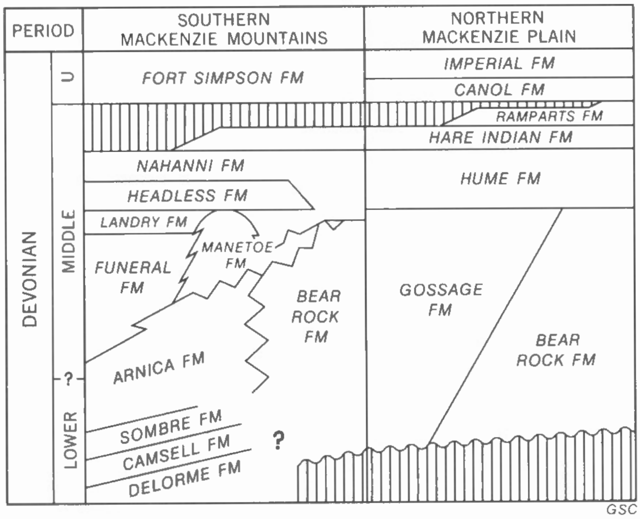


FIGURE 2. Table of formations.

Also described are a variety of sedimentary structures and fabrics. The best examples were photographed and are reproduced in this report. Some of these structures are diagnostic for certain depositional environments and are well known from literature of Recent and ancient carbonate rocks.

In this report the term "sedimentary sequence" is used instead of the term "sedimentary cycle" (Wilson, 1975) because it better describes the lithological and sedimentological changes that occur in upward direction in one prograding sedimentary unit. The term cyclic emphasises the recurrence of each lithology in a succession of units but does not suggest the presence of a hiatus.

Acknowledgments

The writer gratefully acknowledges the co-operation and assistance of his colleagues at the Institute of Sedimentary and Petroleum Geology who have contributed to the understanding of the geology of the District of Mackenzie. Fossils collected from the cores were examined by A.E.H. Pedder and T.T. Uyeno. Thin sections were made by W.O. McEwan, and photographs were taken by B.C. Rutley. The manuscript was critically reviewed by D.G. Cook, A.F. Embry, D. Morrow and G.K. Williams.

STRUCTURAL GEOLOGY

The Dahadinni M-43A well is located near the crest of the Crescent Ridge Anticline in the southern part of the Mackenzie Plain (see Douglas and Norris, 1973). This anticline trends in a northwesterly direction, has a core of Devonian rocks, and is flanked by Cretaceous strata.

In the Dahadinni M-43A well, the strata between depths 3708 and 5767 feet (1130.2-1757.7 m) dip between 10 and 15 degrees and occasionally the bedding dips 30 degrees. A fault of unknown magnitude or direction was intersected at 5767 feet (1757.7 m). Below this fault, between 5767 and 6111 feet (1757.7-1862.6 m), the beds dip between 45 and 90 degrees.

The section below depth 6111 feet (1862.6 m) was only partly examined but it is apparent from the core description in the Well History Report that the abnormal thickness of the Evaporitic member in the Dahadinni M-43A well is due to tectonic complications.

Between 5106 and 5108 feet (1556.1-1556.9 m), the beds dip 60 to 90 degrees and the presence of a fractured zone that includes anhydrite veins indicates that at this depth another fault occurs. It is not known to what extent this fault has affected the stratigraphical succession in the borehole since no duplication of beds was found below it.

The section between depths 4090 and 4460 feet (1246.6-1359.4 m) is repeated between depths 4460 and 4748 feet (1359.4-1447.2 m) along a minor thrust fault (see Fig. 3). Between depths 4455 and 4470 feet (1357.8-1362.4 m), the core is intensely fractured and beds dip approximately 30 degrees. Both the neutron and sonic curves on the borehole logs clearly show the repetition of beds marked by numbers 1 to 8 on Figure 3. The repetition is obscured on the gamma ray curve because the upper part of the Funeral Formation in the section underlying the thrust fault is more argillaceous than the equivalent beds in the section overlying the thrust fault.

In the upper part of the Dahadinni M-43A well, three distinct beds are repeated. The first is a thin pebble bed that overlies an erosional surface (see Fig. 11h). This bed is present at 4121.5 and 4498 feet (1256.2 and 1370.9 m) and is shown twice as marker 2 on Figure 3. A short distance below this pebble bed is an interval containing thin coquina beds which is also repeated, occurring between 4128 and 4130.5 feet (1258.2-1258.9 m) and again at 4500 feet (1341.6 m).

The third distinct lithology that is repeated in the core is an argillaceous unit containing light-coloured, laminated beds which are in places graded or crossbedded. This interval occurs between 4216 and 4265 feet (1285.0-1299.9 m) and is repeated between 4577 and 4595 feet (1395.1-1400.5 m). This bed is shown as marker 5 on Figure 3.

In the section above the thrust fault just below marker 5 on Figure 3 is another steeply dipping and disturbed zone that probably includes a fault dipping at about 60 degrees. The direction of the dip could not be determined. The section between markers 5 and 6 in the upper part of Figure 3 is much thicker than the undisturbed interval between markers 5 and 6 in the lower part of Figure 3.

STRATIGRAPHY

According to the geological map (Douglas and Norris, 1963), the Dahadinni M-43A well was spudded in Upper Devonian shale. Subsurface correlation with nearby wells, using borehole logs, also indicates that Cretaceous strata are absent in the Dahadinni M-43A well. Log correlations suggest that the stratigraphic interval between depths 400 and 3708 feet (121.9-1130.2 m), from which samples are missing, includes a normal succession of Devonian strata comprising the Imperial (incomplete), Canol, Hare Indian and Hume Formations (see Fig. 2). The succession between 3808 and 12 000 feet (1130.2-3657.6 m) was cored and includes the lower part of the Hume, the Funeral and the Bear Rock Formations. Figure 4 shows schematically the succession in the Dahadinni M-43A well between 3430 and 5430 feet (1045.4-1655.6 m) and also shows a comparision between the formal names used at present to

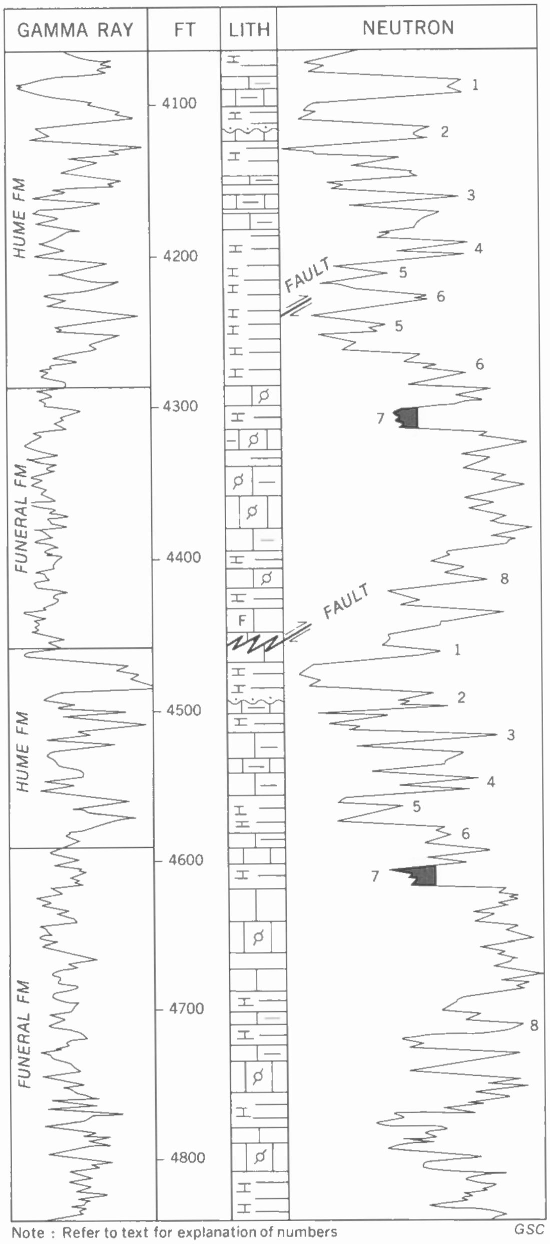


FIGURE 3. *Gamma ray-neutron log of the Dahadinni M-43A well showing duplication of beds between depths 4100 and 4800 feet (1249.6-1463 m).*

subdivide the Lower to Middle Devonian strata. In the northern part of the Mackenzie Plain, the terminology used by Tassonyi (1969) includes the Imperial, Canol, Hare, Indian, Hume, Gossage and Bear Rock Formations. In the southern part of the Mackenzie Mountains, the Devonian succession comprises the Fort Simpson, Nahanni, Headless, Manetoe, Landry, Funeral, Arnica, Sombre, Camsell and Delorme Formations (Douglas and Norris, 1961, 1963; Law, 1971).

The Lower and Middle Devonian succession accumulated in a slowly subsiding topographic depression named the Mackenzie Trough (Douglas and Norris, 1963) located in the area presently occupied by the Mackenzie Mountains (see Law, 1971, Fig. 4). In this trough, Silurian carbonates are overlain by Lower Devonian carbonates and evaporites, which grade upward into Middle Devonian carbonates. A complete but dolomitized section is present in the Pan Am A-1 Mattson Creek No. 1 well (Lat. 61°02'28"N, Long. 123°48'30"W) between 9485 and 1658 feet (2891.0-505.3 m). In the Dahadinni M-43A well, the section is incomplete at the base but serves as a good reference section because it is cored and is not extensively dolomitized. In the following paragraphs, this section is described from the base upward.

Bear Rock Formation

The Bear Rock Formation was proposed by Hume and Link (1945, p. 16) "to describe the brecciated and non-bedded limestones lying below Middle Devonian strata and above a sharp disconformity with well-bedded Silurian limestone below it". The type section is located in the outcrop area at Bear Rock near Fort Norman. In surface sections on the McConnell Range (see Fig. 1), the Bear Rock Formation is composed of fine grained, slightly silty and argillaceous, pale brown to dark grey limestone breccia that weathers yellowish orange (Douglas and Norris, 1961, p. 18).

In the subsurface, the Bear Rock Formation has a different lithological character and consists of interbedded anhydrite and dolostone with brecciated intervals (Tassonyi, 1969). Apparently the anhydritic rocks recrystallize to gypsum at shallow depth. The gypsum is transformed to hydrogen sulphide and calcium carbonate under the influence of anaerobic bacteria. This process is named microbial sulphate reduction (Orr, 1977, p. 585). It is thus apparent that the evaporitic rocks of the Bear Rock Formation can be studied at surface but satisfactory information is obtained only from subsurface sections. This fact was recognized by Tassonyi (1969, p. 41-48) who selected the section present between 930 and 1865 feet (283.4-568.4 m) in the Imperial Vermilion Ridge No. 1 well (Lat. 65°07'51"N, Long. 126°05'00"W) as the reference well for the Bear Rock Formation. In this well two informal members were recognized by Tassonyi: a lower evaporitic member consisting of interbedded anhydritic and dolomitic rocks, and an upper brecciated member consisting of dolomitic rocks. In this report the terms Evaporitic member and Dolomitic member are used, because the term brecciated can be misleading (see discussion of Dolomitic member).

In the Dahadinni M-43A well, the top of the interbedded dolostone and limestone succession is correlated with the top of the Bear Rock Formation and is chosen at a depth of 4898.5 feet (1493.1 m). The base of the Bear Rock Formation was not reached in the well. The formation consists of a lower Evaporitic member and an upper Dolomitic member (or "brecciated" member of Tassonyi, 1969). Both include several rock types which are interbedded or form sedimentary sequences. In most sequences the basal contact is marked by a thin pebble bed; in others, it consists of a thin, dark greenish grey shale parting. The vertical succession of each sequence is different in the two members of the Bear Rock because different lithologies are involved. It is possible, however, to recognize three lithologically distinct units in most of the sedimentary sequences: a basal pebble bed (unit A); a dark-coloured, indistinctly laminated unit (unit B); and a light-coloured, dolomite mudstone (unit C) at the top that contains sedimentary structures related to a "low energy" intertidal or supratidal environment (see Fig. 5). The boundaries between the units are gradational except for the basal contact of unit A. Of the three, unit B attains the greatest thickness and its lithology is the most variable. In the Evaporitic member of the Bear Rock Formation, unit B is represented by dolostone, anhydritic dolostone and nodular bedded or mosaic anhydrite. In the Dolomitic member, unit B is composed of dolostone and limestone.

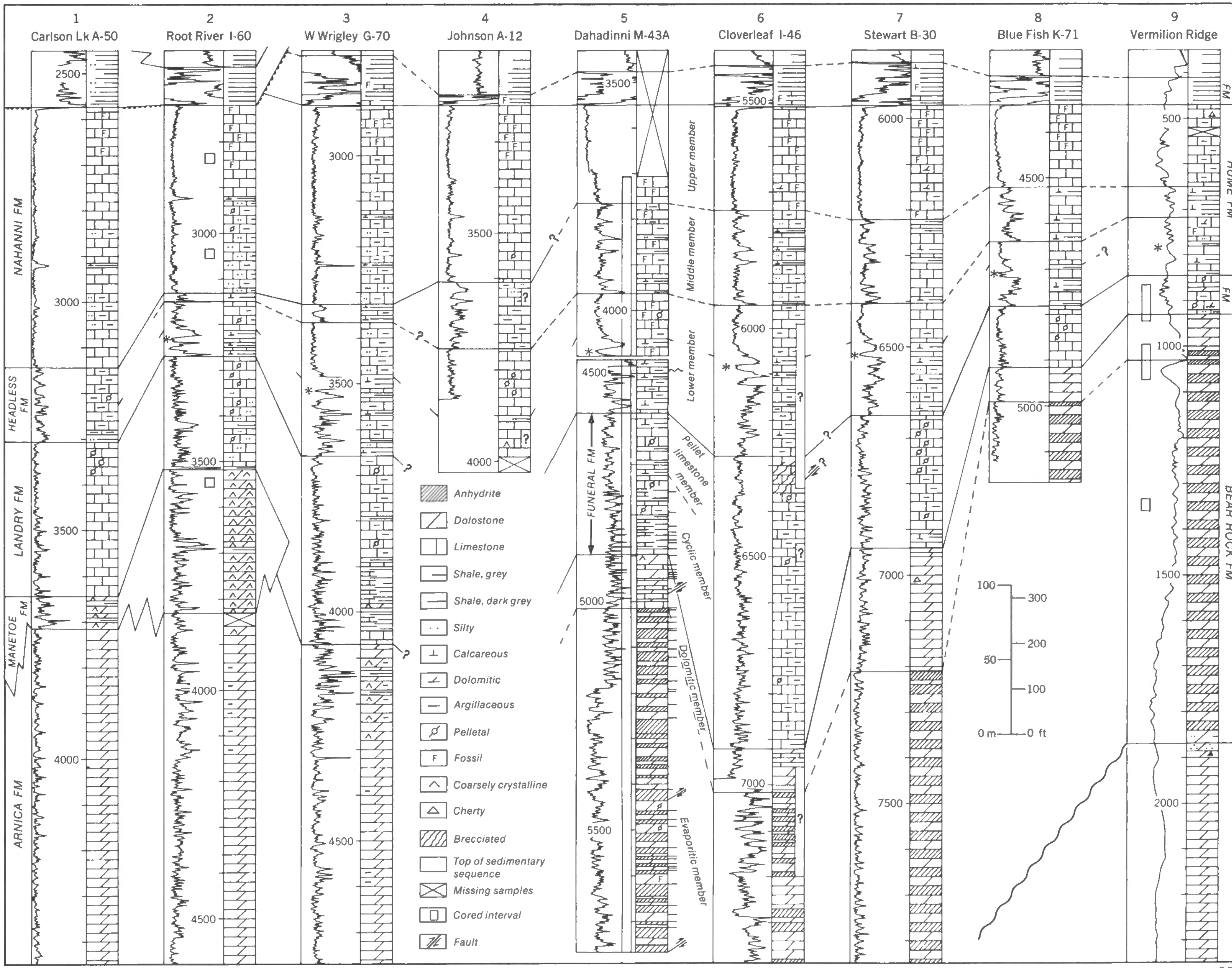


FIGURE 4. Correlation of the Middle Devonian strata of exploration wells 1 to 9, located on Figure 1, using lithology and radioactivity logs.

Evaporitic member

The Evaporitic member of the Bear Rock Formation in the Dahadinni M-43A well occurs between depths 5015 and 10 272 feet (1528.6-3130.9 m). The succession is incomplete at the base and is probably repeated by faulting. A complete section is exposed on the north end of the Dahadinni Range (see Fig. 1). Douglas and Norris (1963) described the succession at "Mount Haywood" as consisting of, in ascending order: 150 feet (45.7 m) of massive breccia provisionally referred to the Camsell Formation; 435 feet (132.5 m) of massive and in part brecciated dolomites of the Arnica Formation; 1000 feet (304.8 m) of massive breccia of the Bear Rock Formation overlain by 550 feet (167.6 m) of argillaceous limestone of the Funeral Formation.

In the Dahadinni M-43A well the succession is comparable. In the basal part of the well, between depths 9749 and 10 272 feet (2971.5-3130.9 m), the Evaporitic member is dominated by dark grey dolostone. This part was named by Williams (1975) the "Arnica platform dolomite". It transitionally underlies a disturbed succession of interbedded dolomitic and anhydritic rocks of unknown thickness. The anhydritic rocks are overlain by interbedded limestone and dolostone, the equivalents of the Funeral Formation at "Mount Haywood".

In this report, the facies dominated by dark grey dolostone between depths 9749 and 10 272 feet (2971.5-3130.9 m) is regarded as an Arnica tongue in the Bear Rock Formation, or as the lower sub-unit of the Evaporitic member. The succession dominated by anhydritic rocks is regarded as the upper sub-unit of the Evaporitic member, and the overlying interbedded limestone and dolostone unit is referred to the Dolomitic member.

Lower sub-unit

The lower sub-unit of the Evaporitic member in the Dahadinni M-43A well occurs between depths 9749 and 10 272 feet (2971.5-3130.9 m). It is incomplete at the base and is overlain with a gradational contact by anhydritic beds of the upper sub-unit of the Evaporitic member. The sub-unit consists of an interbedded succession of greyish brown, grey and dark grey, microcrystalline to very finely crystalline dolostones and minor, thin, pale-coloured anhydrite beds. White nodules of coarsely crystalline anhydrite occur scattered throughout. The succession contains three types of sedimentary sequences which are separated from each other by sharp contacts or thin argillaceous partings. They are named the anhydritic, the laminated dolostone, and the non-laminated dolostone sequences. The anhydrite sequence is typical for the Evaporitic member of the Bear Rock Formation and an example is shown and described in Figure 6.

The two dolostone sequences are commonly present in the Arnica Formation and here the basal shale parting (sequential unit A) is overlain by a thick, grey or dark grey, indistinctly laminated or massive dolostone which includes argillaceous and fossiliferous interbeds (sequential unit B). The fossiliferous beds contain scattered round vugs and white, recrystallized fragments of crinoids, gastropods, brachiopods and Amphipora (see Fig. 7). In both dolostone sequences the colour changes from dark grey to grey in upward direction because the argillaceous content decreases.

An example of the laminated dolostone sequence is shown and described in Figure 7. In the non-laminated dolostone sequence the dark grey, laminated or massive fossiliferous dolostone grades upward to a grey dolostone that has a bioturbated appearance. Anhydrite is present in the

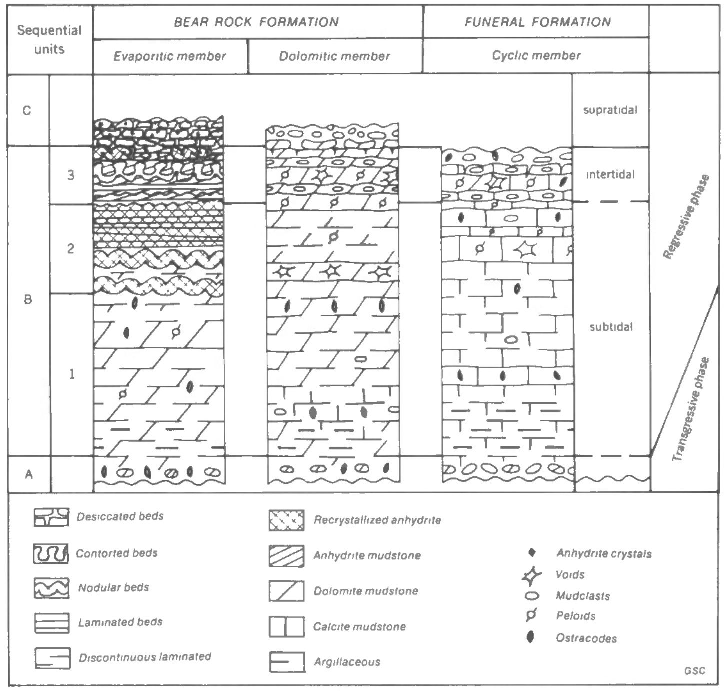


FIGURE 5. *Diagram showing the vertical succession of the sequential units A, B and C, the correlation between regressive and transgressive sedimentary cycles of the Bear Rock and Funeral Formations and their inferred environment of deposition.*

upper part as scattered fine to coarse crystals and near the top the dolostone is peloidal and contains abundant fine to very coarse mud clasts and very coarse anhydrite crystals. This coarse grained packstone is locally indistinctly laminated. In some beds, the light-coloured dolomite mud clasts are leached and the dolostone contains abundant small round vugs. The coarse grained dolomite-packstones vary in thickness from 30 to 130 cm. They are sharply overlain by the dark-coloured, indistinctly laminated beds of the next seqence. Only at one place, depth 9875.5 feet (3010 m), is the packstone overlain by a thin dolostone pebble bed that may be classified as a sequential unit A.

Upper sub-unit

The upper sub-unit of the Evaporitic member, between 5015 and 9749 feet (1528.6-2971.5 m) in the Dahadinni M-43A well, includes the same lithologies as the lower sub-unit but in the upper sub-unit the anhydritic mudstone beds comprise 30 to 50 per cent of the total section. Because of tectonic complications only the upper 800 feet (234.8 m) and the basal 50 feet (15.2 m) of the upper sub-unit were examined in detail. Between 5130 and 5015 feet (1563.6-1528.6 m) and 5478 and 5701 feet (1669.7-1737.6 m), the sub-unit is composed of a repetition of complete sedimentary sequences, which are well marked at the base. The basal contacts between the sedimentary sequences are indicated on the right hand side of the Dahadinni M-43A section shown in Figure 4. There are two types of sedimentary sequences present. In the anhydritic sequence the indistinctly laminated dolostone (sequential unit B) grades upward into nodular bedded anhydrite and laminated anhydrite. In the laminated dolostone sequence the indistinctly laminated dolostone grades upward into a dolostone containing mud clasts and secondary anhydrite. Complete dolostone sequences occur rarely in the upper sub-unit of the Evaporitic member, but their presence indicates that the environment of deposition of the anhydritic and dolostone sequences is very similar.

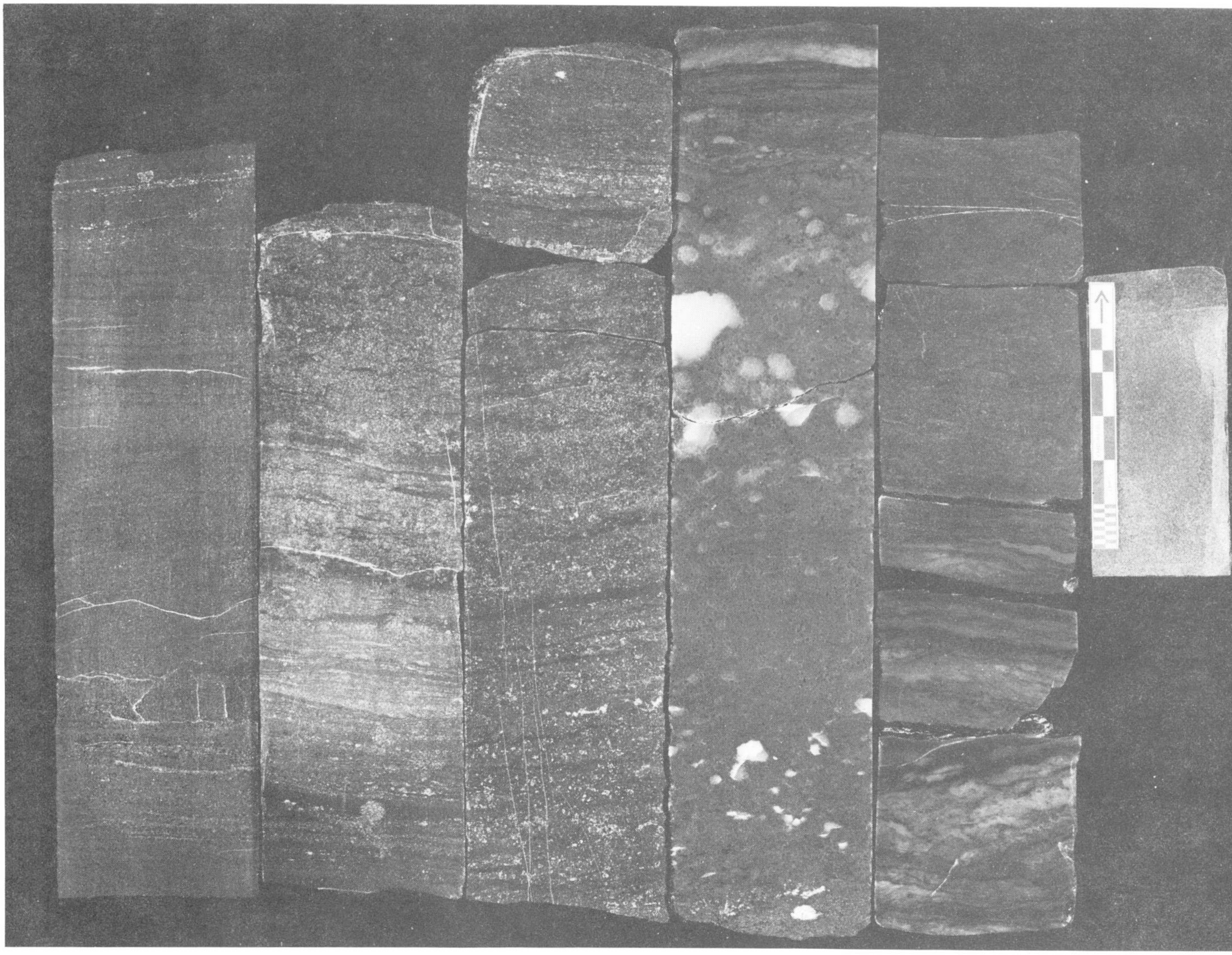


FIGURE 6. *These samples, arranged in five columns, represent a complete regressive sedimentary sequence that grades upward to anhydrite. The samples are from the basal part of the Evaporitic member in the Dahadinni M-43A well.*

The column on the left side of the picture is from depth 10 139.5 feet. It is a grey to dark grey, very thin bedded and laminated, micro- to very finely crystalline dolostone with scattered fine crystals or coarse patches of secondary anhydrite. Rare light-coloured, discontinuous laminae are present and under the microscope several rippled surfaces were noted.

The upward continuation of the left hand sample is present in the second column from the left. A gradual change occurs at the base of this core sample. The amount of light grey dolomite increases in an upward direction and is mixed with the grey and dark grey dolomite in beds that have a bioturbated appearance. Individual burrows are small and deformed, but a large (1 cm) well-preserved burrow occurs in the basal part of the core sample.

The third column from the left was taken from depth 10 137.5 feet and shows the continuation of the nodular, discontinuous parallel laminated, bioturbated dolostone. In the upper part of the column, the beds are ?peloidal and contain scattered anhydrite crystals and small vugs filled with anhydrite. The beds of the first, second and third column belong to the sequential sub-unit B_1.

In the fourth column from the left, the dolostone is anhydritic, light greyish brown, microcrystalline and ?peloidal. Almost half of the volume consists of anhydrite crystals and scattered white anhydrite nodules. The nodules attain their largest size in the area just below the upper contact. The anhydritic dolostone may be classified as a sequential sub-unit B_2. *The upper contact is sharp and is marked by a dark greenish grey, argillaceous layer.*

The upper part of the fourth column and the lower part of the fifth column represent the sequential sub-unit B_3 *and consist of microcrystalline anhydrite. This sub-unit is nodularly interbedded with dark grey argillacous material and contains deformed inclusions.*

The sequential sub-unit B_3 *is overlain with a sharp contact by a grey to dark grey, microcrystalline dolostone. It contains an abundance of scattered light- and dark-coloured, compressed, fine to very coarse mud clasts, and some calcispheres. This unit forms the base of the next sedimentary sequence and is classified as a sequential unit A.*

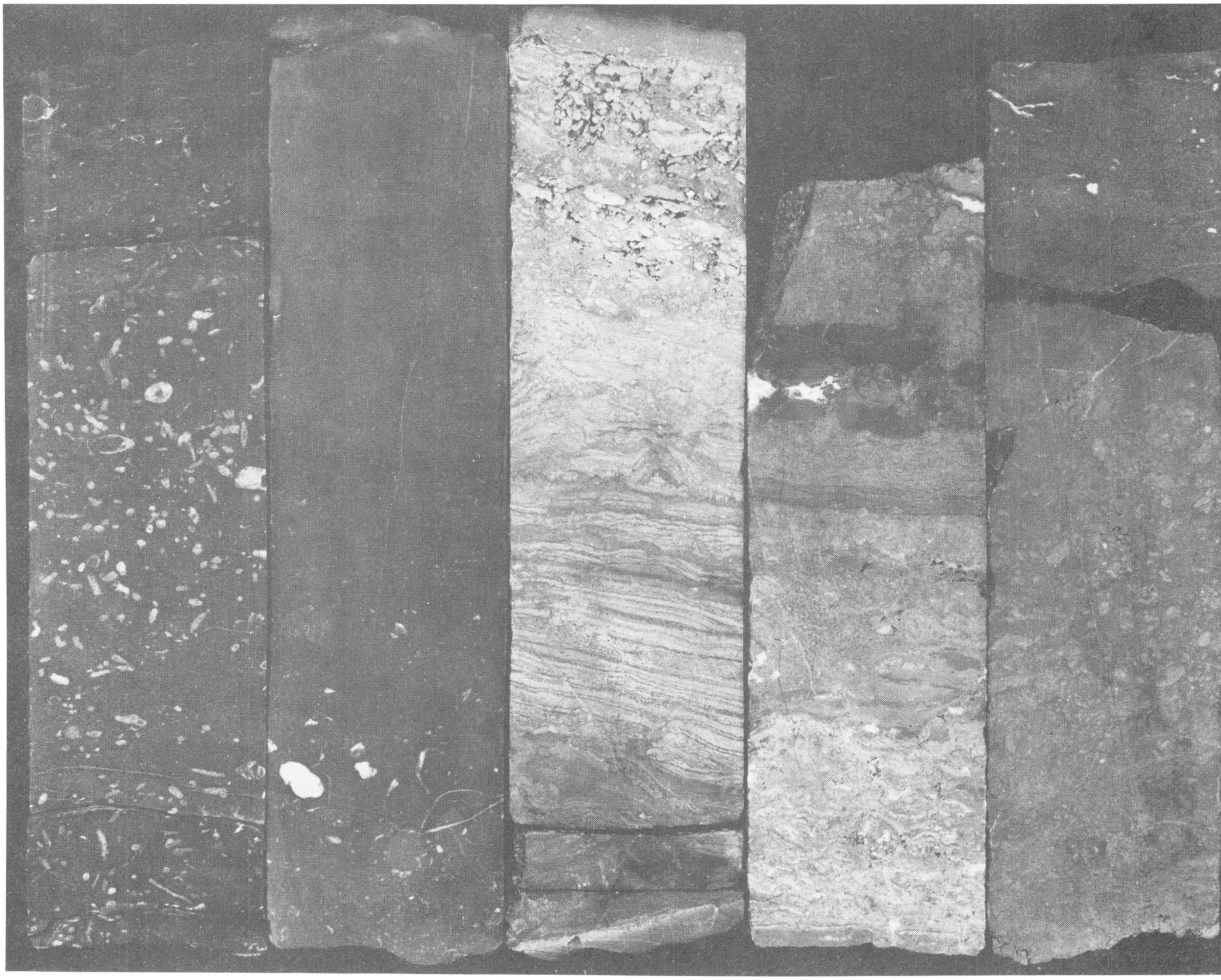


FIGURE 7. Photograph of the regressive sedimentary sequences present between depths 9963 and 9956 feet (3036.7-3034.6 m) in the basal part of the Evaporitic member of the Bear Rock Formation in the Dahadinni M-43A well (scale on Fig. 6). The core samples are arranged in such a fashion that the depth increases from top right to bottom left.

The sample on the left side of the photograph is from 9963 feet (3036.7 m). It is a grey to dark grey, massive, micro- to very finely crystalline, slightly argillaceous dolostone which contains scattered, unsorted fragments of Amphipora, corals, ?ostracodes and brachipods. This lithology is commonly seen in the Arnica Formation and is here classified as a sequential unit B. The base of unit B lies at depth 9997.5 feet (3047.2 m) and unit B is 12 m thick.

Unit B is interbedded with beds such as shown in the second sample from the left (depth 9959 ft, 3035.5 m). This sample represents the upper part of unit B, a grey, microcrystalline dolostone with conspicuous white fragments of gastropods, brachiopods, and crinoids.

In the basal part of the third column from the left (depth 9958 ft, 3035.2 m), the grey dolostone of unit B is interbedded with light brown, microcrystalline dolostone. The light brown beds are irregular and nodular and contain small burrow-like structures. The nodular beds grade upward to a light brown, microcrystalline dolostone containing dolomite-infilled fenestral vugs. It is sharply overlain by a light-coloured unit that contains mud clasts. The pale-coloured, deformed mud clasts are partly supported by a matrix of dolomite-mud and partly cemented by calcite (dark grey spots). This mudstone is classified as a sequential unit C and was probably subaerially exposed at the top.

Unit C is sharply overlain near the top of the third column by a light-coloured dolomite-mudstone containing scattered fine to coarse dolomite mud grains (a thin sequential unit A).

In the lower part of the fourth column, this unit A is overlain by a disturbed laminated, light-coloured bed; another sequential unit C. It consists of deformed mud clasts supported by mud. Scattered dolomite-infilled fenestral vugs are present and near the top of the bed some of the laminated lenses may represent mud-infilled vugs. This disturbed sequential unit C is sharply overlain by another dolomite mudstone which also grades upward into a sequential unit C and consists of deformed mud clasts supported by a mud matrix. Dolomite- and calcite-infilled fenestral vugs are present and the unit is conformably overlain by a dark grey, wavy laminated, argillaceous interval that grades upward into a pebble bed with white dolomite-infilled vugs. This pebble bed may be classified as a sequential unit A and it forms the basal unit of the next sedimentary sequence. In the lower part, this unit A contains dark grey mud clasts in a light brown matrix, in the upper part the mud clasts are light brown and the matrix is dark grey.

At the base of the fifth column, another sequential unit A is present, separated from the underlying unit A by a stylolite. This unit is a dolomite-floatstone and shows the same upward change in composition as the underlying unit A. It is gradationally overlain by grey to dark grey, microcrystalline dolostone containing scattered white fossil fragments. This dolostone is classified as a sequential unit B and grades upward in a light greyish brown, irregular parallel laminated dolostone not shown on the photograph.

FIGURE 8. Core photographs of the Dahadinni M-43A well, Bear Rock Formation, Evaporitic member (natural scale except Fig. b).

a. Contact between sequential unit A and sequential sub-unit B_2; depth 5191 feet (1582.2 m). Lower part (sub-unit B_2) consists of dark grey, micro-to very finely crystalline, somewhat argillaceous and dolomitic anhydrite, with nodular interbeds and nodules of light-coloured, finely crystalline anhydrite. The contact with the overlying unit A is marked by a stylolite. The upper part of the photograph (unit A) is a conglomeratic dolomite-wackestone with abundant dark-coloured, oolitic grains and granules of dolomite, anhydrite or silica, elongate very dark coloured pebbles of silicified oolitic, dolomite mudstone and very pale coloured elongate, in part deformed dolomite mud clasts.

b. Sequential unit A; depth 5191 feet (1582.21 m). This thin section (C-46955) shows the upper part of Figure 8a. The lower part shown in the photograph comprises mainly dark grey and black dolomite. The upper part is light coloured and is extensively silicified. The lower part consists of fine to coarse ooids and elongate mud clasts in a mudstone matrix. Some of the ooids and mud clasts are partly or completely silicified or anhydritized, and in places the matrix is also silicified or anhydritized. The following features are described.

1. *A very dark coloured elongate mud clast consisting of partly silicified dolomite. Remnants of original peloidal fabric are visible and interpeloidal voids (light spots) are filled with silica. Anhydrite has replaced both dolomite and silica in the upper right corner (bright area on photograph).*

2. *Light brown mud clast, consisting of three parts. The light-coloured area in the centre consists of micritic silica; upper dark area is dolomite and lower part consists of coarse silica and anhydrite crystals.*

3. *Elongate pebble reminiscent of shell fragment consisting of microcrystals of dolomite and very fine anhydrite crystals in the centre. The matrix surrounding the pebble is a partly silicified dolomite with light-coloured silicified ooids and dark-coloured dolomitic ooids.*

4. *Two small silicified clasts. The upper one is only partly silicified, the lower one also contains large anhydrite crystals. The matrix in the light area on the lower left side of the lower clasts contains coarse anhydrite crystals.*

5. *Silicified ooids in which part of the original fabric has been preserved.*

6. *Coarsely recrystallized area. Matrix surrounding silicified ooids has been replaced by silica and anydrite.*

7. *Ooids replaced by single anhydrite crystals surrounded by a dolomite matrix. The anhydrite crystals of some ooids are in optical continuity, others have retained a silicified centre.*

8. *Recrystalized area that contains remnants of ooids in a matrix of coarse dolomite and anhydrite crystals.*

9. *Small cavities, infilled with spherulitic chert crystals.*

10. *Fracture, outlined by quartz crystals.*

11. *Small, dark grey fracture that contains anhydrite crystals.*

12. *Single anhydrite crystal, replacing an ooid, present in a silicified matrix.*

13. *Single dolomite crystal, probably replacing an ooid, surrounded by a silicified matrix.*

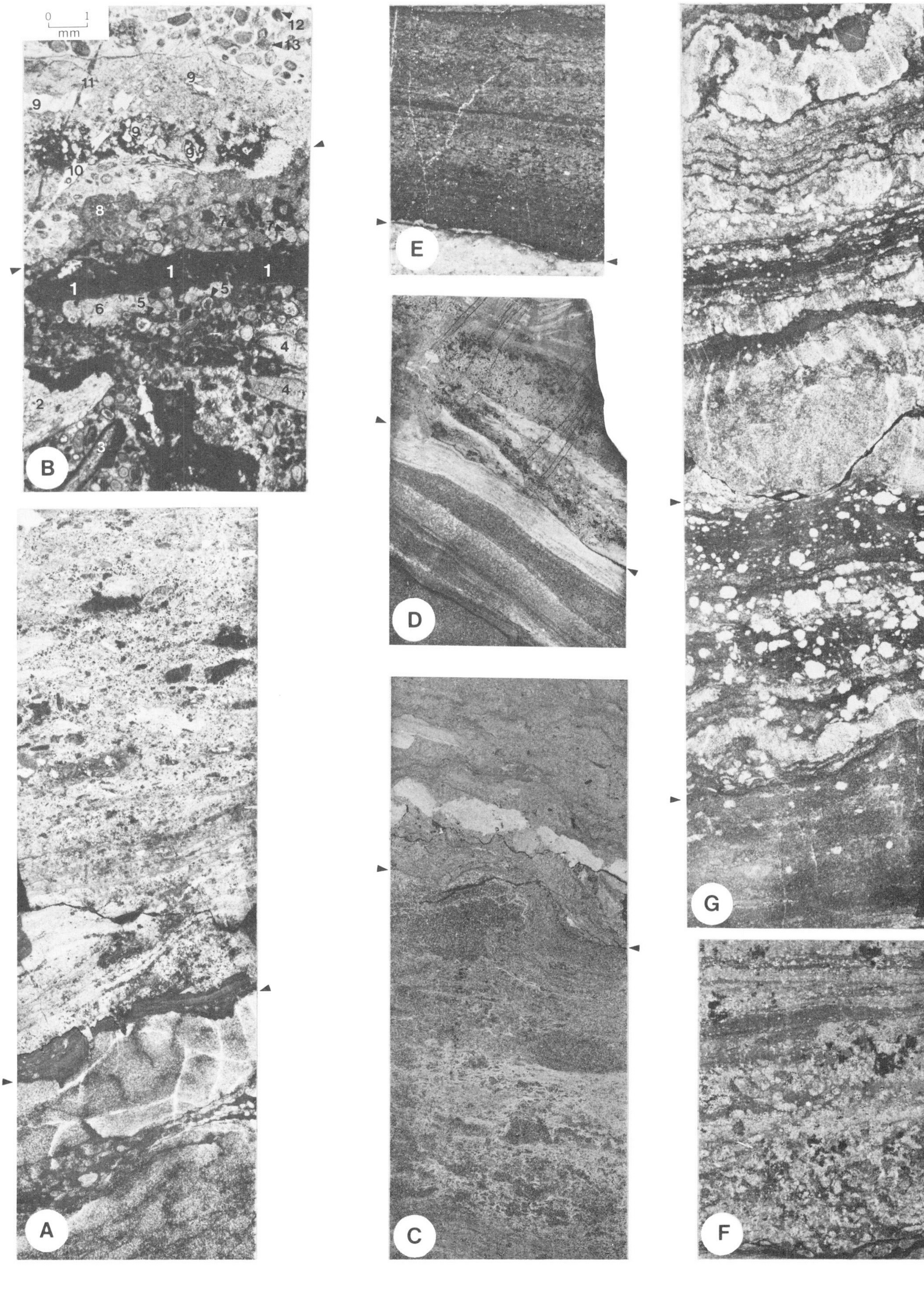
c. Irregular contact between a sequential sub-unit B_3 below, and unit A above. Depth 5478.5 feet (1669.84 m). Sub-unit B_3 is a microcrystalline mixture of dolomite and anhydrite and contains irregular, dark-coloured, deformed anhydrite mud clasts and an anhydrite nodule. The dolomitic parts are pale coloured and the anhydritic parts are grey. The contact with the overlying bed is sharp and has been disturbed. Unit A is a microcrystalline dolostone which contains a layer of pale-coloured dolomitic mud clasts. It was originally a calcite mudstone and the scattered black spots are relicts of the original calcite matrix.

d. Contact between sequential sub-unit B_2 and unit A at 5050 feet (1541.9 m). Lower part (sub-unit B_2) consists of grey, finely crystalline, subfelted anhydrite with light-coloured microcrystalline dolomite layers that contain abundant microscopic ?algal filaments. The contact at the top of a thin, light-coloured, microlaminated dolostone bed is wavy and sharp. The upper part (unit A) has a mottled appearance and is a microcrystalline dolostone with abundant dark-coloured calcitic mud clasts, calcite-infilled ostracodes and large, light-coloured, elongated, somewhat deformed dolomite-mud clasts. At the top of the photograph are closely packed bed fragments.

e. Pale-coloured microcrystalline anhydrite-mudstone of sub-unit B_3, sharply overlain by a very thinly bedded, in places peloidal, dolomite-mudstone (unit A), containing scattered sub-horizontally aligned and calcite infilled vugs. Depth 5557 feet (1693.77 m).

f. Mottled and bioturbated dolomite-mudstone bed of sequential unit B overlain by a very thinly bedded and indistinct, parallel laminated dolomite-mudstone. The bioturbated bed is microcrystalline and contains near the top dark-coloured, fine calcite-infilled vugs. Depth 5120 feet (1560.57 m).

g. Transition between sequential sub-units B_1 and B_2 at 5284 feet (1610.5 m). Three beds are present. The basal bed (sub-unit B_1) is a grey, indistinct, laminated microcrystalline, anhydritic dolostone with "calcispheres" and ostracodes. The next bed (sub-unit B_2) is a microcrystalline anhydrite, indistinctly grey and dark grey laminated, and includes a thin nodular bed near the base. This interval contains conspicuous light-coloured, coarsely crystalline secondary anhydrite nodules, and some poorly preserved anhydrite-infilled ostracodes. The upper bed (sub-unit B_2) consists of very thinly, irregularly and nodularly interbedded, grey and dark grey banded, micro- to very finely crystalline anhydrite, with some light-coloured, secondary anhydrite nodules. The uppermost anhydrite bed in this interval is pseudocontorted.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In the next paragraphs the anhydritic sequence will be discussed first and the laminated dolostone sequence later.

Anhydritic sequence

Unit A. In most sequences, unit A is a thin, prominent, pebbly, dolomite-mudstone or dolomite-wackestone up to 15 cm thick. It contains light-coloured dolomite mud clasts or granules and calcite-infilled ostracodes (see Fig. 8a, c, d). Unit A has a sharp basal contact which commonly is an erosional surface. In sequences where the unit is absent, the contact is marked by a dark grey stylolitic shale parting. Unit A is overlain by an indistinctly laminated dolostone (unit B) with a gradational contact. Only at one place does an anhydritic mudstone directly overlie unit A (at depth 5018.5 ft; 1529.6 m)

A pebble bed present at 5191 feet (1582.2 m) and classified as unit A may represent a condensed sedimentary sequence. It is a dolomite-wackestone with abundant partly silicified ooids and mud clasts which, in the upper part of the bed, are replaced by anhydrite (see Fig. 8a, b). This condensed sequence is in sharp contact with an overlying dolomite-mudstone bed rich in ostracodes and this in turn grades upward into a laminated dolomite-mudstone of sequential unit B.

Unit B. The sequential units B are laminated and are between 0.7 and 9.7 m thick. Those composed of anhydrite show a threefold division. In ascending order the three are: B_1, B_2 and B_3. Sub-units B_1 and B_2 form the bulk of the sedimentary rocks in the evaporitic member.

Sub-unit B_1. Sub-unit B_1 overlies unit A with a gradational contact. In places where unit A is absent, the basal contact is marked by a thin, dark greenish grey shale bed or stylolitic parting. Sub-unit B_1 consists of a dark grey, wavy parallel or discontinuous parallel laminated, micro- to very finely, or very finely crystalline, locally slightly argillaceous dolostone. The dolostone contains scattered, light-coloured, coarse mud clasts and is interbedded with layers that include abundant ostracodes and calcispheres which are in part calcite-infilled (see Fig. 8d). Some sub-units include massive beds with a relict-peloidal or bioturbated fabric and scattered calcite- or anhydrite-filled vugs (see Fig. 8f). The peloidal beds contain scattered ostracodes, and, between 5605 and 5606 feet (1708.4-1708.7 m), gastropods, ?Amphipora and a bulbous stromatoporoid with a diameter of 5 cm.

Sub-unit B_2. Sub-unit B_1 grades upward to sub-unit B_2, a very finely to finely crystalline, light-coloured anhydrite which may be named according to the classification proposed by Maiklem et al. (1969) as bedded nodular, nodular mosaic or aligned felted. The anhydrite is variably dolomitic and includes distorted intervals and thin contorted beds. Most of the distortions observed are related to the segregation of the anhydrite in larger crystals or crystal clusters from a microcrystalline matrix composed of dolomite, anhydrite and minor argillaceous material. Other distortions are probably related to differential compaction.

The gradational lower contact of sub-unit B_2 in Figure 8g and the relict sedimentary structures shown in Figure 9d suggest that the anhydrite probably represents a recrystallized mudstone similar to the anhydrite-mudstone present in sub-unit B_3. The succession of nodularly interbedded dolomite and anhydrite of Figure 8g contains anhydrite-infilled ostracodes, a contorted anhydrite bed and a late generation of small, isolated, light-coloured, anhydrite nodules. The recrystallized anhydrite beds in Figure 9d are crossbedded and contain black shale chips that form a thin lag deposit on top of an erosional surface.

FIGURE 9. *Core photographs of the Dahadinni M-43A well, Bear Rock Formation, Evaporitic member (natural scale except Figs. e and f).*

a. A dolomitic sequential unit B that contains remains of small-scale crossbeds, depth 5647.5 feet (1721.35 m). The interval is a pale-coloured, microcrystalline dolostone with grey, anhydritic layers and patches. Scattered black spots are nodular aggregates of anhydrite. The dolostone was originally a calcite mudstone and remains of the original calcite are present.

b. Desiccation cracks at depth 5123 feet (1561.4 m). The cracks are filled with white coarsely crystalline anhydrite and their vertical extent is limited by bedding surfaces. Host rock is a thin and irregularly bedded succession of light-coloured microcrystalline, dolomite and dark-coloured anhydrite. The dolomite layers are peloidal and contain anhydrite-infilled vugs and ostracodes.

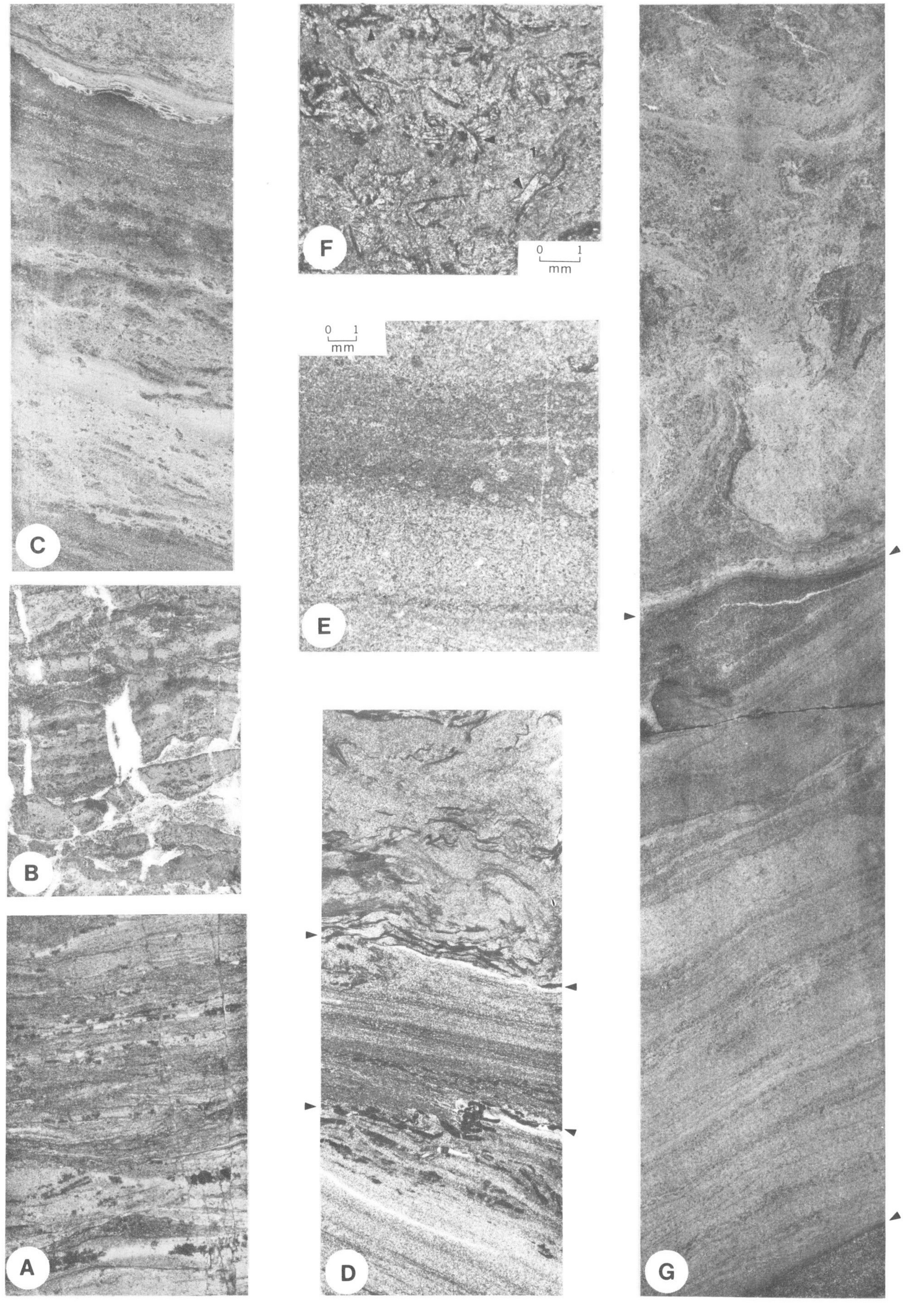
c. Sequential sub-unit B_3 underlying Figure 8e (depth 5557 feet (1693.77 m). Anhydrite-mudstone is microcrystalline and thinly bedded. The light-coloured beds are dolomitic, and contain deformed anhydrite-mud clasts. The dark-coloured beds are indistinct, parallel laminated. Some contacts between light-and dark-coloured beds are scoured surfaces and on this basis the beds may be classified as intertidal deposits.

d. Sedimentary structures in sequential sub-unit B_2 at 5106 feet (1556.3 m). Three laminated, finely crystalline anhydrite beds are present which contain very dark grey shale inclusions. At the erosional contact at the top of the lower bed, shale chips show evidence of having been transported by moving water. The upper bed has a gradational lower contact and here the irregularly shaped shale inclusions are disturbed by slumping.

e. Sequential unit B; depth 5081 feet (1548.68 m). Thin section (C-46954) shows the microcrystalline and laminated fabric of an anhydritic dolomite-mudstone. Dark areas are dolomite and light areas are anhydrite. Very finely to medium recrystallized dolomite grains and crystal aggregates of anhydrite, in places replacing ostracodes, are present.

f. Sequential sub-unit B_3; depth 5017 feet (1529.18 m). Thin section (C-46951B) of a disturbed laminated, microcrystalline, dolomitic, anhydrite-mudstone with light-coloured anhydrite-infilled gypsum pseudomorphs and some anhydrite-infilled ostracodes (not in photograph). Dark grey, argillaceous and dolomitic material fringes the pseudomorphs and also occurs as fragments in the matrix. The fragments may represent debris of an algal mat.

g. Transition between sequential sub-units B_2 and B_3; 5019 feet (1532.8 m). Three beds are present. The basal bed (sub-unit B_2) is a very finely to finely crystalline, aligned-felted anhydrite. The next bed (sub-unit B_3) consists of microcrystalline, wavy parallel interlaminated, light-coloured dolomite and dark anhydrite. This bed is abruptly overlain by a disturbed bed consisting of a mixture of anhydrite and dolomite.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Between 5647 and 5648 feet (1721.2-1721.5 m), a thick sequential sub-unit B_2 contains interbeds of calcareous dolostone which are discontinuous parallel laminated and cross-laminated (see Fig. 9a).

Sub-unit B_3. In complete anhydritic sedimentary sequences, sub-unit B_2 is overlain by sub-unit B_3, a non-argillaceous, delicately laminated, very dolomitic anhydrite-mudstone which is not extensively recrystallized. Sub-unit B_3 contains a variety of primary and secondary sedimentary structures. Some beds are discontinuously, wavy parallel laminated, and contain scoured surfaces, anhydrite mud clasts and crossbeds (see Fig. 9c, g). Other beds contain deformations (see Figs. 9b, g, 10a).

In the upper part of a complete anhydritic sequence, situated between 5126 and 5121 feet (1562.4-1560.9 m), sub-unit B_3 consists of irregularly interlaminated dolomitic and anhydritic mudstones and contains deformations such as shown on Figure 9b. In these beds the dolomitic mudstone is dominant and contains white, secondary anhydrite in discontinuous vertical fractures that probably represent desiccation cracks. These desiccated beds correspond to unit C of the laminated dolostone sequence described below.

The deformations shown in Figures 9g and 10a may represent slump structures related to lateral movements of water rich sediment along a slope or may represent deformations related to the pressure exerted on the sediment layer by overlying beds.

A disturbed bed similar to the sample shown on Figure 9g contains fine crystals reminiscent of gypsum crystals (see Fig. 9f) and it is possible that this bed originally was a mush of dolomite and gypsum.

FIGURE 10. *Core photographs of the Dahadinni M-43A well and the Vermilion Ridge No. 1 well (Fig. e).*

a. Bear Rock Formation, Evaporitic member. Three beds of the sequential sub-unit B_3 at 5084 feet (1549.6 m). Light coloured bed is laminated and consists of dolomitic microlaminae separated by micronodular laminae of grey anhydrite. The dolomitic laminae are folded and in places broken up. Discontinuous anhydrite veinlets are present; one vein is cut off at the upper contact, which is sharp and only slightly disturbed. Upper bed consists of irregular and somewhat discontinuous interlaminated dolomite and anhydrite.

b. Bear Rock Formation, Evaporitic member. Succession of two sedimentary units, depth 5588.5 feet (1703.37 m). Basal unit (sub-unit B_3) is a parallel laminated, microcrystalline, somewhat dolomitic, anhydrite-mudstone. It is overlain by a thin interval consisting of curled up bed fragments. This desiccated layer is sharply overlain by a disturbed bed (a sequential unit C). Unit C is an unsorted mixture of grey microcrystalline anhydrite and pale-coloured, anhydritic dolomite, containing very light coloured, fine to medium mud clasts. The disturbed bed is sharply overlain by a grey, microcrystalline anhydrite-mudstone. This thin bed forms the top of the sequential unit C and is overlain by a dolomitic unit A not shown on the photograph.

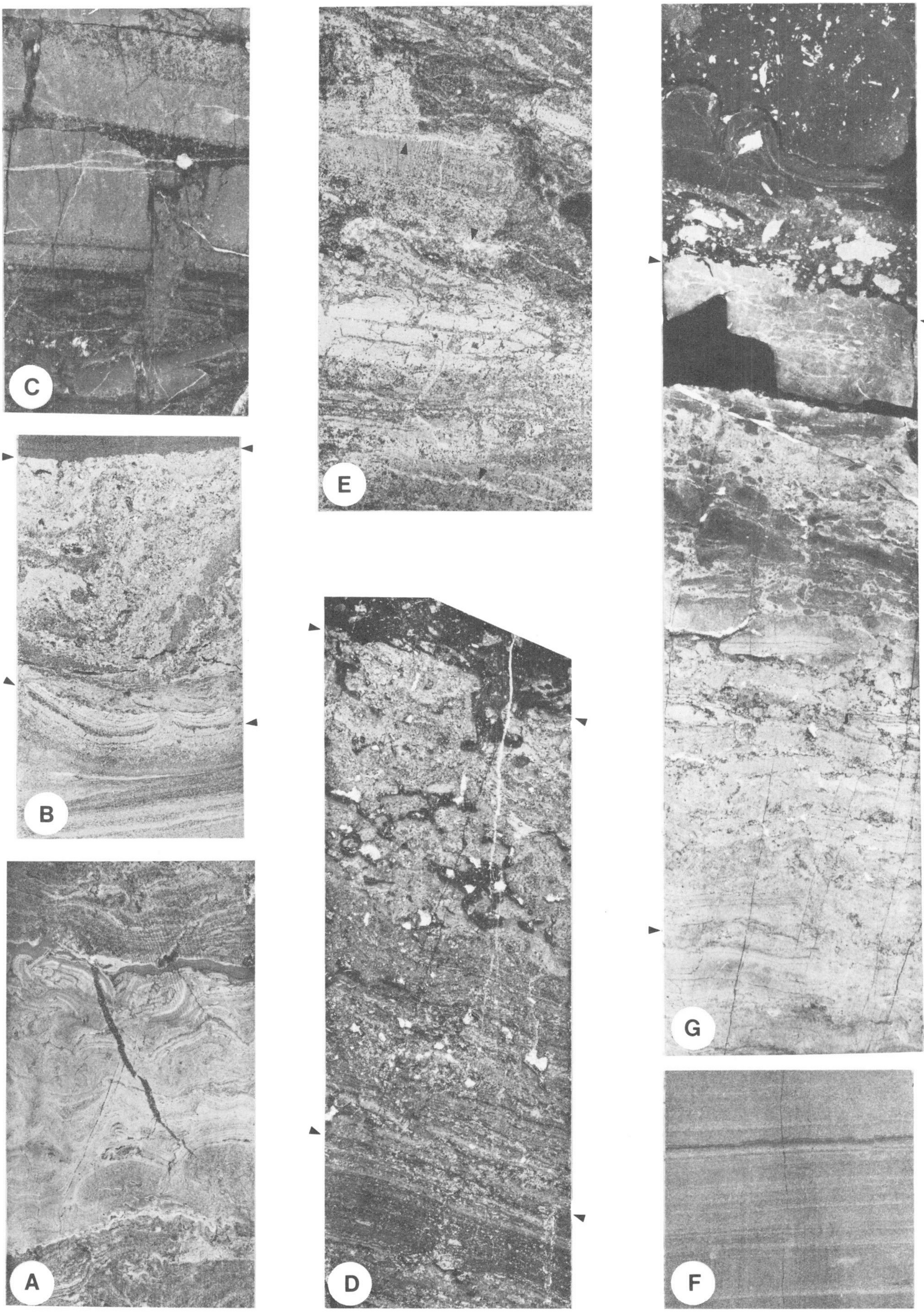
c. Desiccation fractures in a dolomite-mudstone at depth 5501.5 feet (1676.85 m). The interval is transitional between sequential unit B and C, and is equivalent to the sub-unit B_3 in the anhydritic sequence. The dark-coloured beds and layers contain 50 per cent microcrystalline anhydrite. A few small light-coloured anhydrite nodules are also present.

d. Succession of three sequential units in a microcrystalline dolostone at 5065 feet (1543.81 m). The basal unit (unit B) is greyish brown, discontinuously, parallel laminated, and contains scattered, light-coloured, coarse mud clasts. It is transitionally overlain by an irregular, non-parallel laminated unit (unit C) that contains an abundance of burrows, fenestral vugs and ostracodes. Some of the burrows are partly filled with laminated mud or fine-grained sediment including ostracodes. The fenestral vugs and the ostracodes are filled with clear anhydrite. The upper contact of the unit C is very irregular. The upper unit (unit A) in the photograph is dark grey and contains scattered mud clasts derived from the underlying unit C.

e. Vermilion Ridge No. 1 well, Bear Rock Formation, Dolomitic member; depth 1015 feet (309.37 m). Irregular and discontinuous interbedded and interlaminated dolostone and anhydrite. Light-coloured areas consist of dolomite-mudstone; dark-coloured areas are anhydrite. The original sedimentary structures (bedding and the outline of mud clasts) are disrupted by anhydrite infilled desiccation cracks and by the growth of anhydrite nodules. Anhydrite is also present as irregular veins, inclusions and as blocky crystals. In the pale-coloured veins (indicated by arrows), the anhydrite has been transformed to gypsum.

f. Bear Rock Formation, Dolomitic member, lower part sequential unit B; depth 4934 feet (1503.8 m). Even, parallel-laminated, micro- to very finely crystalline, slightly argillaceous dolostone. Some laminae are very finely to finely crystalline at the base and grade upward to micro- to very finely crystalline at the top.

g. Bear Rock Formation, Dolomitic member, contact between two sedimentary sequences; depth 4930 feet (1502.6 m). Lower part of photograph represents sequential units B and C and consists of a porous, microcrystalline, thinly and discontinuously bedded, laminated dolostone at the base. It grades upward to a microcrystalline dolostone which contains elongated and laminated bed fragments, rounded granules and somewhat deformed mud clasts (unit C). This lithology in turn grades upward to a 8 cm thick interval of which only the upper part is shown at the base of the upper sample in the photograph. This interval has a cloudy appearance and is a porous, microcrystalline dolostone with abundant pale-coloured, fine to coarse dolomite mud grains and scattered, rounded dolomite mud granules that have a light-coloured surface. The top part of this interval contains an abundance of closely packed, elongated mud pebbles. The dolomite mudstone of unit C is erosionally overlain by a conglomerate bed (unit A). This unit is a dark-coloured, microgranular limestone containing light-coloured dolomite pebbles and granules. The pebble bed is gradationally overlain by a dark-coloured argillaceous limestone rich in white fossil fragments and contains light-coloured patches of partly dolomitized limestone and, in the basal part, a thin folded bed of very dark grey pyritic shale.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In the disturbed interval shown on Figure 10a, the dolomitic layers act as competent beds in the microfolds whereas the anhydritic layers display flowage. This suggests that the dolomitic layers were coherent before the distortion occurred. Since the disturbed bed in the photograph is overlain conformably by another mudstone bed, the distortion must have occurred before the overlying bed was deposited. The dolomitic layers may have been held together by algae as in Shark Bay (Davies, 1970).

Unit C. In the sedimentary sequences that grade upward to anhydrite-mudstone, sequential unit C is normally absent and either the sub-unit B_2 or the sub-unit B_3 forms the top of the sequence (see Fig. 8a, c, e). However at 5588.5 feet (1721.3 m), the upper part of sub-unit B_3 contains a desiccated bed that is overlain by a disturbed laminated, fine to coarse grained anhydrite-wackestone (see Fig. 10b). The wackestone bed classified as an anhydritic unit C, is in turn overlain by a laminated anhydrite mudstone that underlies a sequential unit A of the next sequence.

Laminated dolostone sequence

Three sedimentary sequences in the Evaporitic member of the Bear Rock Formation do not grade upward to anhydritic mudstone. The first sequence present between 5495 and 5507 feet (1674.8-1678.5 m) consists of a stylolitic shale parting at the base (unit A), a massive, microcrystalline, anhydritic dolostone with scattered patches of anhydrite (unit B) overlain gradationally by a very thinly bedded and parallel laminated, microcrystalline dolostone containing mud-infilled desiccation fractures (see Fig. 10c). These beds are in places relict peloidal, are locally porous and contain scattered, fine anhydrite crystals. They are overlain gradationally by a medium grained peloidal and oolitic, dolomite-wackestone that contains anhydrite cement. Both the desiccated beds and the peloidal wackestone are classified as C units.

The second sequence occurs between 5121 and 5141 feet (1560.8-1566.9 m) and consists of four units. Unit A is a dolomite floatstone, 45 cm thick, with subrounded dolostone clasts as large as 1 x 2 cm. Sub-unit B_1 is an irregularly laminated, very finely to finely crystalline dolostone and is in sharp contact with overlying B_2. Sub-unit B_2 is a nodular bedded to massive anhydrite that does not contain relict sedimentary structures. Sub-unit B_3 is a thinly interbedded and irregularly laminated bed of anhydrite and dolomite mudstone. The dolomite-mudstone beds are in places peloidal and contain ostracodes. At depth 5123 feet (1561.4 m), sub-unit B_3 is disturbed by vertical desiccation cracks filled with anhydrite (see Fig. 9b).

The third complete dolostone sequence occurs between 5064.5 and 5071 feet (1543.6-1545.6 m). It consists of sub-unit B_1 at the base, a recrystallized anhydrite bed (sub-unit B_2) and a thin (15 cm thick), brown irregularly laminated dolostone bed at the top that represents unit C (see Fig. 10d). Unit C is a peloidal dolomite-wackestone rich in coarse to very coarse mud clasts. The bedding in the lower part of the unit C is disturbed. The upper part of unit C is "lumpy" and contains irregular, anhydrite-infilled vugs and deformed mud-infilled burrows. The upper contact of unit C is highly irregular and disturbed by burrows.

Dolomitic member

The Dolomitic member of the Bear Rock Formation in the Dahadinni M-43A well corresponds to the "Brecciated member" of the Bear Rock Formation in the Vermilion Ridge No. 1 well (see Fig. 4). According to Tassonyi (1969, p. 44), "The brecciated member consists of brown and grey microcrystalline to finely crystalline or microgranular dolomite which, under the microscope may show a microbrecciated pattern". He assumed that these dolomites are the subsurface equivalents of the conspicuous limestone and dolomite breccias of the Bear Rock Formation in outcrop. A detailed examination of the two cores in the "Brecciated member" of the reference well (Vermilion Ridge No. 1) showed that the microbrecciated pattern mentioned by Tassonyi is absent. The core consists of a discontinuous, wavy parallel-laminated, light-coloured, micro- to very finely crystalline dolostone typical of sub-unit B_1 (see Fig. 11b), with one thin (2.5 cm thick) dolomite-wackestone bed containing abundant dolomite mud clasts. In the basal part of the member in the Vermilion Ridge well, secondary anhydrite is present in the form of irregular beds and nodules. The anhydrite is associated with disrupted and ?desiccated dolomite mudstone beds typical of unit C of the dolostone sequence described in this report (see Fig. 10e). Fractured beds or brecciated intervals are notably absent in both cores of the reference well and the name "Brecciated member" for the rock unit is not appropriate.

In the Dahadinni M-43A well, the Dolomitic member comprises the interval between 4895 and 5015 feet (1491.9-1528.6 m). The lower boundary of the member is chosen at the highest occurrence of massive anhydrite and the upper contact is marked by the highest prominent dolostone bed (Tassonyi, 1969). In the Dahadinni M-43A well, the basal contact is not represented in the core, but it lies at the base of a 13.1 m thick, incomplete dolomitic limestone sequence. In the same well, the upper contact is marked by a 60.9 cm thick bed of coarsely crystalline dolostone of a type commonly found in the Manetoe Formation.

The sedimentary sequences in the Dolomitic member range in thickness from 6 cm to 13.1 m and consist of two or three units.

Unit A. Unit A is thin and overlies an erosional surface. It is a dolomite-floatstone and consists of light-coloured, dolomitic mudstone clasts and a grey, dolomitic or dark grey, calcareous mudstone matrix (see Fig. 10g). The pebbles and clasts are derived from the underlying unit.

Unit B. Unit B overlies unit A with a gradational contact or overlies a thin, very dark grey shale bed. It consists of a dark grey, wavy, parallel- or discontinuous wavy parallel laminated, argillaceous limestone, in places dolomitized to very finely crystalline to microcrystalline dolostone (see Fig. 10f). The recrystallization has partly destroyed the delicate laminations and sedimentary structures are indistinct. The laminated facies contains thin beds rich in ostracodes, "calcispheres", small gastropods, ?foraminifera, "Charophyta oogonia" (see Appendix II) and, rarely, tube-form corals. Thin beds rich in light-coloured, fine to coarse mud clasts are present also. In the lower part of the sedimentary sequence, unit B is argillaceous, interlaminated with wavy, very dark grey shale and, in places, grades to a calcareous shale. The upper part of unit B is grey or greyish brown and includes scattered light-coloured aphanitic or indistinct peloidal limestone beds containing small irregular vugs filled with calcite or dolomite. These beds are partly dolomitized to a very finely crystalline or microcrystalline dolostone. Also present in the upper part of unit B are micro- to very finely crystalline, pyritic dolostone beds which display light and dark grey mottles in a pattern described by Dixon (1976). The upper boundary of unit B is gradational and is marked by the disappearance of dark grey, argillaceous beds.

Unit C. Unit C forms the top of the sedimentary sequence and is a light-coloured laminated dolostone. This dolostone is microfragmental or micro- to very finely crystalline, in places peloidal and locally includes an abundance of pale-coloured mud clasts and elongate mud pebbles. Some beds contain mud clasts with curled-up edges, other beds contain abundant, discontinuous, vertical cracks filled with mud or white dolomite cement. In places the white dolomite constitutes 30 per cent of the rock volume. Unit C of the dolostone sequence is shown in the lower part of Figure 10g. The upper contact of unit C is visible in the upper half of the photograph, and it consists of a light-coloured dolomite mudstone that has a reworked appearance and contains small, scattered, randomly oriented, rounded mud pebbles that have pale-coloured rims.

Environment of deposition

In this discussion three terms are used to characterize the marine environment. The term subtidal is used to describe an environment that was permanently submerged; the term intertidal for the zone that is alternately flooded and exposed; and the term supratidal for the environment that is infrequently flooded (see Ginsburg, 1975, p. 234). In addition "low energy" and "high energy" are used to describe the inferred level of turbulence at the sediment-water interface.

The discussion on the environment of deposition is probably best started by commenting on the striking similarity between the sedimentary structures described from the sequential unit C in the Dolomitic member of the Bear Rock Formation and those seen in Recent carbonates of tidal flats (see Ginsburg, 1975, Sec. III). By analogy, the dolostone of sequential unit C, which forms the top of the sedimentary sequence in the Bear Rock Formation, may be classified as an ancient intertidal to supratidal deposit. Since the carbonates of sequential units A and B are closely related to sequential unit C, it is possible to infer the sedimentary environments of the complete carbonate sequence and construct the diagram presented in Figure 5. The analogy between anhydritic, dolomitic and calcareous sequences in the diagram is so striking that one may conclude that the differences in the sedimentary and diagenetic structures of the units B and C across the diagram are related to a difference in chemical composition of the original sediment, and that the difference in chemical composition is in turn related to the salinity of the water and to the environment of deposition.

In the Dahadinni M-43A well, the dolostone beds of the sequential unit A of the Bear Rock Formation locally contain calcite-infilled ostracodes and relicts of a calcite cement. This suggests that the unit was deposited as a calcareous mud. The fact that the ostracodes have retained their original shape suggests that the mud was lithified at an early stage. Sequential unit A forms the base of the sedimentary sequence and overlies a surface that represents a period of non-depositon or destruction. In some examples, unit A is a floatstone and mud clasts occur scattered in the mud matrix. These floatstone beds may be storm deposits. In most examples, however, unit A contains only one layer of mud clasts and the mud matrix is laminated. It is suggested that these beds are storm deposits from which fine material is removed by current and wave action. If these coarse deposits overlie an ancient land surface and grade upward into marine mudstones, there is reason to believe that they are a basal transgressive deposit.

The laminated dolostones of sequential unit B are probably deposits originally composed of calcareous mud containing small ostracodes and "calcispheres". Since sequential unit B does not contain any features related to intermittent exposure, the author has classified it as a sub-tidal deposit. The presence of delicate scoured surfaces in the discontinuous parallel-laminated mudstone, the lack of abundant coarse material and the presence of massive peloidal and bioturbated interbeds suggest that the environment was shallow subtidal and "low energy".

In the anhydritic sequence the laminated dolostone (sub-unit B_1), is gradationally overlain by nodular bedded and nodular mosaic anhydrite. The nature of the boundary suggests that the upward change in lithology originated through an increase in supply of calcium sulphate. This change in lithology reflects a change in chemical composition of the surrounding water and is probably related to excessive evaporation. It is thus argued that the recrystallized anhydrite of sequential sub-unit B_2 represents a sub-tidal or lagoonal mud deposit composed of calcium sulphate and minor carbonate. This mixture was altered after deposition, exposure and burial to crystalline anhydrite by the process of dewatering, recrystallization and compaction without an additional supply of calcium sulphate.

The nodular anhydrite beds present in the lower part of sequential sub-unit B_2 are similar to the anhydrite beds shown by Bebout and Maiklem (1973, Fig. 5a, b, c) as representatives of the "deep-water anhydrite facies" of the Muskeg Formation in northern Alberta.

It is worth noting that, in the Dahadinni M-43A well, clearly displacive anhydrite nodules are not common. The presence of small, displacive nodules related to anhydrite-filled ostracodes has been discussed (see Fig. 8g). The displacive anhydrite nodules in unit B of Figures 6 and 8c did not originate from fossils but may have grown from anhydrite-infilled vugs. In these samples the nodules underlie a scoured surface that may represent a period of emergence. It is possible that the nodules have grown during this period of emergence.

In the Vermilion Ridge No. 1 well, most of the anhydrite of the Evaporitic member is present in the form of displacive nodules or nodular beds. The anhydrite has disrupted the original bedding and has in places completely replaced the host rock. This form of anhydrite has a diagenetic origin and resembles the replacement anhydrite described from Holocene carbonate sediments in the Abu Dhabi Sabkha (Butler, 1970, facies 4). Accumulation of this type of anhydrite occurs in a supratidal environment and is related to the upward movement of mineral-rich groundwater due to evaporation at the surface (Kinsmen, 1966). It is emphasized here that this type of replacement anhydrite is not restricted to beds classified as supratidal by their primary sedimentary fabric but also may occur in beds representative of all other marine evironments. The presence of diagenetic anhydrite indicates only that the unit was exposed at a later stage. It is thus quite possible that a unit is a sub-tidal deposit yet contains nodular "supratidal" anhydrite.

In the Dahadinni M-43A well, anhydrite is also present in the form of anhydrite-mudstone (sub-unit B_3). The mudstones are delicately parallel-laminated, in places crossbedded (Fig. 9g), or contain scoured surfaces and scattered mud clasts (Fig. 9c). Other anhydrite-mudstone beds are disturbed (Fig. 9g) and contain relicts of gypsum crystals or algal bound laminae (Fig. 10a). These sedimentary structures suggest that sub-unit B_3 was deposited in a "low-energy" intertidal or very shallow subtidal environment.

Sedimentary structures produced by prolonged subaerial exposure characterize the supratidal environment; they include nodular anhydrite, cemented crusts (caliche), soil horizons, plant roots and karsted surfaces (Ginsburg, 1975, p. 234). In the Bear Rock Formation, only the first two of these structures were noted in the sequential unit C or in beds transitional between units B and C. Diagenetic anhydrite nodules are present in Figures 6 and 8c; desiccated beds are shown in Figures 9b, 10b and 10c.

Diagenesis on a microscopic scale, probably related to subaerial exposure and the upward movement of groundwater, is present in the upper part of the oolitic bed present at depth 5191 feet (158.2 m) in the Dahadinni M-43A well. This bed (shown in Fig. 8a) is classified as a condensed sequence and overlies a recrystallized anhydrite bed with an irregular contact, and is in turn erosionally overlain by a thin dolostone bed with ostracodes. The oolitic dolostone bed shows several stages of recrystallization (see Fig. 10b), including (after the process of early lithification): (1) a complete dolomitization and silification of some ooids and mud clasts; and (2) in the upper part of the bed, local replacement of the micritic matrix, the ooids and the mud clasts by coarsely crystalline anhydrite, silica and dolomite. The second phase of recrystallization is probably related to subaerial exposure and excessive evaporation. This 13 cm thick bed probably was deposited originally in an intertidal environment and became subaerially exposed at a later stage. The duration of the exposure, however, was not long enough to initiate the prolific growth of replacement anhydrite seen in the Evaporitic member of the Bear Rock Formation in the Vermilion Ridge No. 1 well.

Deposits similar to the Bear Rock Formation

Upward-shoaling evaporitic cycles (Wilson, 1975), similar to the regressive sedimentary sequences described above, are found in the Upper Miocene Gessoso-Solififera Formation of Sicily. At the base are even-bedded arenitic marls that change upward into even parallel laminated gypsum. The gypsum contains sedimentary structures typical of a "high-energy" environment (crossbedding and oscillation ripples). Some beds contain mud-cracked surfaces or consist of edge-wise conglomerates. The laminated gypsum passes upward into massive beds composed of crystalline gypsum (see Schreiber et al., 1976).

The Rainbow anhydrite facies of the Middle Devonian Muskeg Formation in northeastern Alberta contains sedimentary sequences of dolostone and anhydrite that are very similar to the sequences described here from the Evaporitic member (compare Figs. 6 and 8g with Bebout and Maiklem, 1973, Fig. 3). Bebout and Maiklem (1973) describe a "Typical Elk Point Sabkha cycle" consisting of 4 units: a basal laminated dolomite; an algal dolomite with angular anhydrite nodules; a bedded nodular mosaic anhydrite; and an upper unit of bedded mosaic anhydrite. The basal unit is equivalent to sub-unit B_1 and the upper two units are equivalent to sub-unit B_2 in the Bear Rock sequence. Possible representatives of sub-unit B_3 are also shown by Bebout and Maiklem (ibid., Fig. 4).

Conclusions

If the interpretation of the sedimentary environment of the sequential units A, B and C of the Bear Rock Formation is correct, three conclusions can be made. Firstly, the sedimentary sequences of the Bear Rock Formation are "upward-shoaling evaporitic cycles". Secondly, the occurrence of the anhydrite sediments in the Bear Rock Formation is restricted to "low energy" shallow subtidal, intertidal and supratidal environments. Thirdly, the sequences are separated from each other by periods of non-deposition or emergence. During these periods the formation of diagenetic, nodular anhydrite took place in a supratidal environment and the landward side of the sequential deposits was being eroded.

One can explain the apparent lowering of the water level in two ways. The first explanation assumes that it is caused by excessive evaporation in a basin that has become isolated from the ocean. The second explanation assumes that it is relative and is caused by the fact that, at least locally, the rate of sediment accumulation is faster than the rate of subsidence.

Because the Bear Rock Formation in the Dahadinni M-43A well has so many features in common with carbonate tidal flat deposits, the author prefers the second explanation. It is concluded that the Bear Rock Formation represents a "low enery" tidal flat deposit of carbonates and sulphates that accumulated in a "marine" nearshore environment at the eastern margin of a slowly subsiding basin (the Mackenzie Trough) under extreme arid conditions.

Gossage Formation

The name Gossage Formation was introduced by Tassonyi (1969) to describe the carbonates that are stratigraphic equivalents of the Bear Rock Formation, situated between the Hume Formation above and the "Ronning Formation" below, in the central part of the Great Bear Plain. Tassonyi (1969, Fig. 10) has mapped this unit in the Norman Wells area. Here the Gossage Formation is thin and does not show the three distinct subdivisions recognizable in the subsurface farther north. This condensed succession consists of limestone and is easily traced in the subsurface to the Dahadinni M-43A well (see Fig. 4).

The carbonates present between 845 and 930 feet (257.5-283.5 m) in the Imperial Vermilion Ridge No. 1 well (Lat. 65°06'51"N, Long. 126°05'00"W) belong to the informal Pellet Limestone member of the Gossage Formation (Tassonyi, 1969, Fig. 10). In this well, the formation was partly cored (see Fig. 4) and it consists of greyish brown aphanitic limestone and peloidal limestone interbedded with minor amounts of light-coloured, calcareous siltstone and thin beds of dark grey argillaceous limestone (see Fig. 11c). Toward the base, light greenish grey ("waxy"), silty shale interbeds are present. The member is sparsely fossiliferous and contains ostracodes, calcispheres and Syringopora-like corals. The base of the Gossage Formation in the Vermilion Ridge well is marked by a 60.9 cm thick, light-coloured, dolomitic and silty shale bed. The contact with the Bear Rock Formation below is not represented in the core and core pieces near the contact are misplaced.

Funeral Formation

In the southern part of the Mackenzie Mountains, the stratigraphical equivalents of the Gossage and Bear Rock Formations were mapped as the Arnica, Landry and Manetoe Formations (Douglas and Norris, 1961, 1963; Gabrielse et al., 1973; Aitken and Cook, 1974). In the Virginia Falls and Root River map-areas the upper part of the Arnica, the Manetoe and the Landry Formations grade laterally into shaly beds of the Funeral Formation (Douglas and Norris, 1961). The type section of the Funeral Formation lies on Nahanni Plateau and is described by Douglas and Norris (1960) as the section of "map-unit 17". Although the Funeral Formation is not continuously mappable to the north, Douglas and Norris (1963) noted its presence at "Mount Haywood" at the north end of the Dahadinni Range (see Fig. 1). At "Mount Haywood" the Funeral overlies massive dolomite and limestone breccia of the Bear Rock Formation and is overlain by the Headless Formation. The Funeral Formation is approximately 167.6 m thick in a partly exposed section and consists of recessive, dark and light grey to brownish and olive-grey, variably argillaceous, laminated, peloidal, cryptocrystalline to finely biogenic limestone. Fossils from these beds are of Middle Devonian age (Douglas and Norris, 1963, p. 18).

At "Mount Haywood" the Funeral Formation occupies the same stratigraphic position as the Gossage Formation farther north.

In the subsurface, the facies change of the Arnica, Landry and Manetoe Formations into shaly equivalents is shown on Figure 4. It is possible to recognize equivalents of the Landry Formation in the upper part of the shaly equivalents in the Dahadinni M-43A well, but the writer has assigned the complete section situated between the Headless and the Bear Rock Formations to the Funeral Formation.

In the Dahadinni M-43A well, the Funeral Formation is present between 4288 and 4895 feet (1306.9-1491.9 m). A detailed examination of cores and borehole logs shows that this interval contains a duplication of strata associated with a fault zone between 4455 and 4470 feet (1306.9-1362.4 m) and a complete section is present between 4588 and 4895 feet (1398.4-1491.9 m). In both sections, the upper contact of the formation is picked at the top of a prominent, massive 3.6 m thick, dark greyish brown, fine to medium, peloidal and fossiliferous limestone unit that has gradational contacts. The lower contact of the formation in the section between 4588 and 4895 feet (1398.4-1491.9 m) is chosen at the top of a 60.9 cm thick, coarsely crystalline dolostone bed. The coarsely crystalline dolostone has replaced a fossiliferous bed containing tabulate corals.

It is possible to subdivide the formation in the Dahadinni M-43A well into two units. The lower unit is a thinly interbedded succession of dark-coloured, unfossiliferous, argillaceous limestone and marl; it has the same sequential character as the Bear Rock Formation. The lower unit is overlain gradationally by a thinly interbedded succession of argillaceous limestone, peloidal limestone and marl in which the presence of sedimentary sequences is less evident. This succession contains conodonts of an Eifelian age (see Appendix I). In the following discussion, the two units are referred to the Cyclic and the Pellet Limestone members. The upper part of the Pellet Limestone member is lithologically similar to the Landry Formation of Douglas and Norris (1963) and Aitken and Cook (1974), and correlates with the informal Pellet Limestone member of Tassonyi (1969) in the Vermilion Ridge No. 1 well (see Fig. 4). The two members do not constitute recognizable map-units and have not been extended beyond the Dahadinni M-43A well. They are introduced only to facilitate the following description.

Cyclic member

The Cyclic member overlies the Bear Rock Formation with a conformable contact at a depth of 4895 feet (1491.9 m). The top of the member is chosen at a depth of 4724.5 feet (1440.0 m) and corresponds to the sharp contact at the top of the last recognizable sedimentary sequence indicated on the section (see Fig. 4).

The Cyclic member consists of marl, argillaceous limestone and peloidal limestone corresponding to units A, B and C of the sedimentary units described in the Bear Rock Formation (see Fig. 5).

Unit A is thin (3-10 cm), and has a sharp, basal contact in places marked by erosion. The top of the limestone unit that underlies the contact is often discoloured (see contact on Fig. 11a) and shows small-scale erosional features. Similar contacts have been described from the Upper Devonian Duperow Formation by Dunn (1975, Pl. 10) as "firm grounds" and "hard grounds". Unit A is either a very dark marl or a dark grey, very argillaceous limestone with abundant matrix-supported mud clasts and rounded mud pebbles up to 9 x 1.5 cm in diameter. The mud clasts and pebbles have the same lithology as the underlying bed.

Unit A is overlain gradationally by unit B which has two parts (see Fig. 11e). The lower part consists of a dark grey, pyritic, indistinctly laminated marl or a very argillaceous limestone. In places, this lower part is intercalated with thin, argillaceous, nodular limestone beds which contain abundant ostracodes, tentaculitids and calcispheres. The marl is dark grey and contains, in places, layers rich in light grey calcareous specks. The upper part of unit B overlies the lower gradationally and is a dark greyish brown, argillaceous limestone or an aphanitic limestone. The limestone is indistinct peloidal, contains scattered ostracodes, calcispheres, tabulate corals and calcite-filled vugs. In some sequences, this lithology grades upward to a greyish brown, laminated and peloidal limestone classified as a sequential unit C.

Unit C contains thin beds with abundant light brown mud clasts, elongated mud pebbles and ostracodes. In the thin peloidal beds and layers, the interpeloidal voids are filled with calcite, and some scattered voids are filled with white dolomite. At a depth of 4779 feet (1456.6 m), unit C is represented by a 15 cm thick coquina limestone bed composed of subhorizontally arranged brachiopod shells.

Pellet Limestone member

The interbedded limestone and marl succession of the Pellet Limestone member does not contain the sedimentary sequences described above. The base of the member is chosen at a depth of 4724.5 feet (1440 m), the highest recognizable sedimentary sequence of the Cyclic member. The upper contact is represented twice in the core and is chosen at the top of a prominent limestone unit. The complete section below the fault shown on Figure 3 is present between 4588 and 4724.5 feet (1398.4-1440.0 m). The lower part of this interval consists of very dark grey marl and variably argillaceous, dark greyish brown limestone. Sharp contacts corresponding to the basal contact of sequential unit A were observed only at two places. A sharp contact at a depth of 4632.5 feet (1411.9 m) occurs at the base of a thin (2 cm) limestone bed that contains flat mud pebbles and very coarse mud clasts. The sharp contact at a depth of 4598 feet (1401.5 m) is overlain by a very dark grey shale bed that grades upward into a thinly interbedded and interlaminated succession of limestone and marl which may represent the lower part of sequential unit B. The top of this limestone unit marks the top of the Gossage Formation in the section below the fault (see Fig. 3).

The section of the Pellet Limestone member above the fault is cut off at the base and is present between 4288 and 4470 feet (1306.9-1362.4 m). This interval is less argillaceous than the Pellet Limestone member below the fault and comprises thick- and thin-bedded units. The thick-bedded units are composed of dark greyish brown, somewhat argillaceous, very finely to coarsely fragmental or fine to medium peloidal limestone. The limestone is indistinctly laminated, in places peloidal, and contains scattered calcite-infilled vugs. Fossils are outlined conspicuously in white calcite (see Fig. 11d) and include gastropods, ostracodes, tabulate corals, and calcispheres (see Appendix II). The thin and nodular-bedded units consist of interbedded dark-coloured argillaceous limestone and marl. The argillaceous limestone is very finely to finely fragmental and is, in places, very fossiliferous (crinoidal debris and ostracodes). The marl beds are laminated and commonly contain sedimentary microstructures such as graded beds and lenticular, inclined laminated beds. Sediment-infilled burrows are present locally. In places, the dark grey marl contains an abundance of white calcareous specks.

The lithologies of the Pellet Limestone member may be classified as an interbedded succession of sequential B-units. The lower part of the sequential unit B is represented by a very dark grey, pyritic, even and parallel laminated marl (see Fig. 11e, lower part) which is thin bedded, nodular and interbedded with dark-coloured argillaceous limestone. The marl contains locally numerous white calcareous specks. The argillaceous intervals in the lower part of sequential unit B are interbedded with thin limestone beds that contain ostracodes, calcispheres, tentaculitids, brachiopods and crinoidal debris. In places the bedding is curved, non-parallel laminated (see Fig. 11f) and includes crossbeds. The very thin beds and laminae are graded and were deposited under the influence of currents and wave-induced turbulence.

The upper part of the sequential unit B is represented by massive dark greyish brown limestone beds, up to 60 cm thick (see Fig. 11e, upper part). These beds are somewhat argillaceous, micro- to finely fragmental or indistinct "lumpy" and peloidal and contain small, scattered, irregular vugs filled with calcite. The limestone beds contain scattered light-coloured corals, gastropods, ostracodes and calcispheres interbedded with thin-bedded, argillaceous, indistinctly laminated and in places peloidal limestone and marl.

Environment of deposition

In the Funeral Formation of the Dahadinni M-43A well, the carbonates of sequential unit C in the Cyclic member contain sedimentary structures similar to those seen in recent and ancient tidal flat carbonates (see Ginsburg, 1975). The laminated peloidal limestone beds are interbedded with layers containing abundant mud clasts, elongate mud pebbles and ostracodes and show the winnowing effects of currents. They may be classified as intertidal or shallow subtidal deposits. The sharp contact at the top of unit C commonly includes a "hard ground". This may indicate a period of non-deposition in a marine environment or a period of emergence (Bathurst, 1975, p. 395).

FIGURE 11. *Core photographs of the Dahadinni M-43A well and the Vermilion Ridge No. 1 well (Figs. b, c). Natural scale.*

a. Funeral Formation, Cyclic member; depth 4859.5 feet (1481.1 m). Contact between sequential unit B below and unit A above. Unit B is a light-coloured, slightly pyritic calcite-mudstone with patches and microfossils (ostracodes). The upper contact is sharp, irregular and shows pale discolouration. Unit A is a dark grey calcite-mudstone with patches of grey and contains abundant granules and small light-coloured mud clasts.

b. Vermilion Ridge No. 1 well; Bear Rock Formation, Dolomitic member; depth 1002 feet (305.40 m). Light brown, very finely crystalline, porous and permeable dolostone with abundant dark grey argillaceous laminae. Remnants of thin shell fragments, peloidal fabric and elongated mud clasts are discernible.

c. Vermilion Ridge No. 1 well; Gossage Formation, Pellet Limestone member; depth 882 feet (268.83 m). Three beds are shown. A basal dark coloured bed, interbedded with dark grey, irregular undulating or stylolitic shale laminae, consists of a calcite-mudstone. The mudstone contains up to 10 per cent of very fine to fine peloids, ostracode shells and "calcispheres". The white spots on the photograph are secondary dolomite crystals. Toward the top, the bed becomes lighter coloured and contains grey mud clasts up to 1.5 cm in length. Most mud clasts have a light-coloured rim. The upper contact of the basal bed is marked by a stylolite (marked by arrows). Overlying the dark brown limestone is an irregularly bedded, lighter coloured interval consisting of a very peloidal calcite-mudstone with elongated mud clasts. The peloids are in places oolitic and range in size from fine to medium. The mud clasts are grey coloured with a light rim and are abundantly present near the top of the bed. The upper bed is laminated and pale coloured; it consists of a calcareous quartz siltstone grading to a silty calcite-mudstone, and contains abundant fine to medium mud clasts and microfossil fragments.

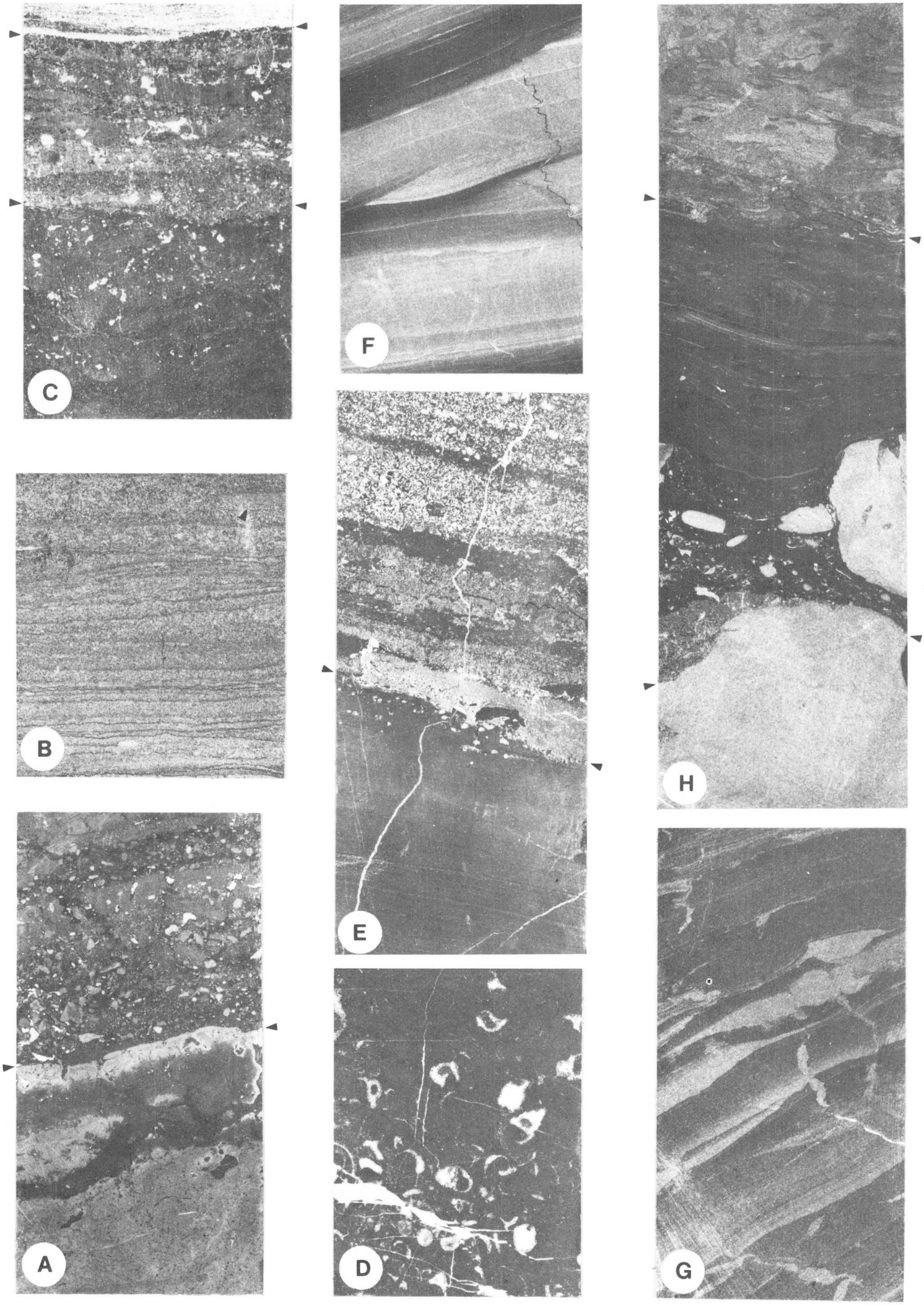
d. Funeral Formation, Pellet Limestone member; depth 4437 feet (1342.3 m). Limestone, dark grey, aphanitic or indistinct peloidal, with abundant unsorted fragments of microfossils and gastropods.

e. Funeral Formation, Pellet Limestone member; depth 4377 feet (1334.1 m). Contact between dark grey, pyritic, even parallel laminated, very argillaceous limestone (lower part unit B) and light-coloured, partly microcrystalline dolomitized, aphanitic limestone above. The upper bed is medium peloidal and contains ostracodes; it may represent the upper part of the sequential unit B. Contact marked by a stylolite.

f. Funeral Formation, Pellet Limestone member; depth 4611 feet (1405.4 m). Wavy, nonparallel and wavy, parallel interlaminated and thinly interbedded light grey marl and dark grey shale. Interval is slightly pyritic and shows scoured surfaces, graded beds, discontinuous, inclined laminated beds and crossbedding.

g. Hume Formation, Lower member, basal sub-unit; depth 4233 feet (1290.2 m). Very thin, discontinuous, graded beds and sediment-infilled burrows are present in a dark grey and grey, wavy, nonparallel interlaminated succession of marl and argillaceous, microfragmental limestone.

h. Hume Formation, Lower member; depth 4121.5 feet (1256.2 m). Erosional contact between limestone below and marl above, that may represent the base of a sedimentary megacycle. The limestone is light grey, microfragmental and is nodularly interbedded with dark grey shale (not in photograph). The marl is very dark grey and contains light-coloured, in part pyritic limestone grains, granules and pebbles. The lower contact of the marl is very sharp, the upper contact gradational. It is overlain by dark grey, bioturbated, argillaceous micro- to very fine fragmental limestone containing patches rich in microfossil fragments.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In the argillaceous carbonates of unit B, the structures related to current and wave action are absent and these sediments probably accumulated in a subtidal environment below wave base. The presence of ostracodes and calcispheres suggest a semi-restricted lagoonal setting. The pebble beds of unit A may represent the remains of a destructive phase in the sedimentary history of the succession. In most examples, unit A overlies a "hard ground" surface and grades upward to a marine mudstone. This combination indicates a period of non-deposition or destruction followed by a relatively rapid rise in sea level and is typical of the "shoaling upward shelf cycles" described by Wilson (1975, p. 281-318).

In the Pellet Limestone member, structures related to current and wave action are present in some of the argillaceous units. They include graded beds and small-scale crossbeds (see Fig. 11f). These micro-structures, the presence of marine fossils such as tentaculitids, crinoids and brachiopods together with ostracodes, the absence of well-marked regressive sedimentary sequences with pebble beds at the base and the absence of "hard grounds" or erosional surfaces suggest continuous sedimentation in a subtidal or lagoonal environment. The thick, indistinct peloidal and fragmental limestone beds lack diagnostic sedimentary structures.

Hume Formation

The name Hume Formation was introduced by Bassett (1961) to describe the fossiliferous Middle Devonian limestone situated between the Bear Rock and Hare Indian Formations in the northern Mackenzie Mountains. Tassonyi (1969) defined the formation in the subsurface of the northern Mackenzie Plain and chose the Imperial Loon Creek No. 2 well (Lat. 65°8.07'20"N, Long. 126°18'51"W) as reference. In this well, the formation consists of three informal members: an Upper, a Middle and a Lower member. These members were correlated southward by Tassonyi (1969, Fig. 10) and, in the Dahadinni M-43A well, the Hume Formation shows a similar three-fold subdivision (see Fig. 4). Here the Lower, Middle and the basal part of the Upper members were cored. The correlation shown on Figure 4 suggests that the Lower and Middle members are approximately equivalent to the Headless Formation as defined in the subsurface by Law (1971). The Upper member correlates approximately with the Nahanni Formation. In the Dahadinni M-43A well, the Hume Formation lies between 3456 and 4288 feet (1080.8-1306.9 m) and the lower part is duplicated between 4470 and 4588 feet (1362.4-1398.4 m) by a fault (see Fig. 3).

Lower member

In the Dahadinni M-43A well, the lower member of the Hume Formation is represented twice (see Fig. 3). The section present between 4470 and 4588 feet (1362.4-1398.4 m) is incomplete at the top. The section between 3964 and 4288 feet (1208.2-1306.9 m) is complete but includes a fault zone at 4236 feet (1291.1 m). In the complete section, both the upper and lower contacts of the Lower member are gradational and the member can be subdivided in three lithologic sub-units.

The basal lithologic sub-unit present between 4201 and 4299 feet (1286.5-1306.9 m) and between 4555 and 4588 feet (1388.3-1398.4 m), has affinities with the Funeral Formation and is marked at the top by an erosional contact that may represent a major break in sedimentation. It is a dark-coloured, thinly and nodularly bedded succession of marl and argillaceous limestone. The limestone beds are dominant in the lower part of the basal sub-unit and are very similar to the limestone beds present in the Pellet Limestone member of the Funeral Formation. They are dark greyish brown, micro- to very finely fragmental, in places fine peloidal and very fossiliferous. Fossils include ostracodes, small gastropods, calcispheres, brachiopods, tentaculitids, and rare crinoidal debris. Some of the limestone beds in the basal unit contain mud clasts.

The argillaceous beds are dominant in the upper part of the basal lithologic sub-unit and form the distinct interval shown on Figure 3 as log-marker 5. This log-marker consists of a very dark grey, in places pyritic marl that is interbedded with thin argillaceous limestone beds, and contains light-coloured, inclined laminated and crossbedded or graded beds. Sediment infilled vertical burrows are also present (see Fig. 11g).

The uppermost part of the basal lithologic sub-unit includes an interval dominated by limestone containing thin coquina beds.

The top of the basal lithologic sub-unit is marked by an erosional surface below a dark-coloured argillaceous pebble bed (see Fig. 11h) that is represented twice in the Dahadinni M-43A well.

The middle lithologic sub-unit present between 4221 and 4062 feet (1286.5-1238.1 m) contains two thick limestone beds which are useful markers in the subsurface (see Fig. 4). This sub-unit has a gradational upper contact and a sharp, erosional lower contact (see Fig. 11h). It consists of a dark-coloured, interbedded succession of thin and nodular beds of variably argillaceous limestone, marl and shale. The limestone beds have gradational contacts and contain irregular, wavy shale partings. The limestone is greyish brown, microfragmental to aphanitic, slightly pyritic, and is in places very fossiliferous (crinoidal debris, corals, brachiopods, gastropods, ostracodes, tentaculitids, calcispheres).

The upper lithologic sub-unit present between 4062 and 3964 feet (1238.1-1208.2 m) has transitional contacts and consists of a poorly and irregularly interbedded succession of fossiliferous limestone and some shale. The limestone is variably argillaceous and contains very fine quartz sand and silt, is micro- to very finely fragmental with up to 20 per cent fossil fragments (stromatoporoids, corals, gastropods, brachiopods, ostracodes, tentaculitids, foraminifera, and calcispheres). The fossils were identified by A.E.H. Pedder of the Institute of Sedimentary and Petroleum Geology, Calgary (see Appendix II).

Middle member

This member is represented in the Dahadinni M-43A well by the interval situated between 3964 and 3765 feet (1238.1-1147.6 m). It has gradational contacts and consists of an interbedded succession of thin and, in places, nodular beds of variably argillaceous limestone, marl and silty shale. The limestone is greyish brown, aphanitic to finely fragmental and contains scattered debris of crinoids, brachiopods, ostracodes, tentaculitids, gastropods, corals and rare bulbous stromatoporoids. The argillaceous intervals consist of dark grey, thinly interbedded marl and silty shale. The marl beds contain flattened tentaculitids on the bedding surfaces.

Upper member

Only the basal part of the Upper member is present in the core. The lower contact is gradational and is chosen at a depth of 4765 feet (1147.6 m). It is represented by poorly bedded, nodular, bioturbated limestone, mottled greyish brown and dark grey, which contains abundant dark grey irregular shale or marl partings. The limestone is variably argillaceous and silty, very fossiliferous. It contains 10 to 20 per cent of unsorted fossil fragments which occur scattered in a micro- to very finely fragmental matrix. The limestone is partly dolomitized, the dolomite crystals being very fine. Fossils include crinoidal debris, brachiopods, ostracodes, small gastropods, and calcispheres. The fossils were identified by A.E.H. Pedder and are indicative of a Middle Devonian, Eifelian age (see Appendix II).

Environment of deposition

Only the basal lithologic sub-unit of the Lower member of the Hume Formation contains beds deposited under the influence of current and wave action. These beds include two thin coquina beds and one argillaceous interval with very thin, graded and cross-laminated beds. They may be classified as marine subtidal deposits.

A significant erosional contact is present at the top of the basal sub-unit which may correlate with a local unconformity at the base of the Ebbutt Member of the Willow Lake Formation in the subsurface of the Great Slave Plain (Law, 1971) and with the postulated unconformity between the Upper and Lower members of the Chinchaga Formation in the subsurface of northern Alberta (Belyea, 1971). A photograph in the Ram Plateau area of the southern Mackenzie Mountains in an unpublished report by Brady and Wissner (1961) shows the presence of an angular unconformity at the base of the Headless Formation, and it is possible that this angular unconformity represents the same event.

The remainder of the Hume Formation above this erosional surface probably represents the deposits of one sedimentary megacycle. This megacycle has a transgressive character and contains a marine fauna of Middle Devonian age (see Appendix II). The lack of sedimentary structures related to wave and current action, the muddy character of the limestone and the presence of a marine fauna suggest that the limestone of the Lower and Middle members of the Hume Formation accumulated in a subtidal, sheltered, shallow-water environment.

POROSITY DISTRIBUTION AND HYDROCARBON POTENTIAL

The Dahadinni M-43A well is one of several exploratory tests in the Wrigley area that have been drilled to evaluate a northwest-trending anticlinal structure. At the time of writing, none of these wells has encountered a trace of oil or gas.

From the available subsurface and outcrop data, it appears that the most prospective Middle Devonian reservoir rock is the white, coarsely to very coarsely crystalline dolomite of the Manetoe Formation. According to Douglas and Norris (1963, p. 32 34) and Tassonyi (1969, Fig. 10), this formation was penetrated twice in the borehole of the Imperial Redstone No. 1 well (Lat. 64°11'42"N, Long. 124°38'19"W), but it was not tested (see Hume, 1954, p. 99).

Porous intervals of white dolomite are not restricted to the Manetoe Formation. They also occur in the fractured beds that contain faults and may also be present in the peloidal beds of the Gossage or Landry Formations.

The borehole logs of the wells drilled in the Wrigley area indicate that the limestone beds of the Hume, Landry and Gossage Formations are devoid of porosity, and that the very finely and finely crystalline dolostone beds of the Bear Rock Formation are locally porous. They were tested between 3990 and 4185 feet (1216.1-1275.5 m) in the Decalta et al. Gulf Amhess Wrigley I-54 well (Lat. 63°13'33"N, Long. 123°54'32"W), but only mud was recovered. Scattered porosity also occurs in the dolostone of the Arnica Formation. It was tested in the Shell Wrigley G-70 well (Lat. 63°09'17"N, Long. 124°11'50"W) between 4049 and 4250 feet (1234.1-1295.4) and yielded water-cut mud.

In the Dahadinni M-43A well, the limestone beds of the Hume, Landry and Gossage Formations are only porous and permeable if they contain a fractured fault zone. In a number of wells "circulation was lost" in the borehole when the well was being drilled through the Hume or Gossage Formations and it is possible that the drilling mud disappeared in fracture zones similar to the ones seen in the cores of the Dahadinni M-43A well. The "lost circulation zones" were tested in some places and gave good recoveries of sulphurous salt water or sulphurous fresh water.

In the Dahadinni M-43A well, a number of dolomite-mudstone beds of the sedimentary unit C in the Dolomitic member of the Bear Rock Formation are permeable and porous, but their thickness does not exceed 12 cm. Some of the dolostones of the sequential sub-unit B in the Evaporitic member of the Bear Rock Formation are also porous. Because of the small diameter of the hole no drill-stem tests were run to evaluate their potential as a reservoir.

No work has been done to evaluate the hydrocarbon potential of the Devonian succession in the well but T.T. Uyeno has indicated the colour of the conodonts found in the core (see Appendix I). The colour may be used as an index to organic metamorphism (Epstein et al., 1977) and is related to the stage of hydrocarbon maturation. The conodonts between the depths of 4622 and 4628 feet (1408.7-1410.6 m) have a "Conodont Color Alteration Index" of 4 1/2 and 6, indicating that one may expect that all Devonian hydrocarbons have been transformed to methane and graphite.

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APPENDIX I

Report on 9 lots of conodont samples from the Candex et al. Dahadinni M-43A well located at Latitude 63°52'59"N, Longitude 124°39'15.1"W, western District of Mackenzie (NTS 95N) by T.T. Uyeno.

Depth and Stratigraphy	Conodonts and age	GSC Loc.
4622.5-4625.0 ft (1530.8-1531.6 m) Funeral Formation (332 g)	Icriodus aff. I. angustus Stewart and Sweet of Bultynck (1972) (2 I elements; small form) age: early to mid-Couvinian/Eifelian; Pelekysgnathus pedderi-Polygnathus parawebbi (early form) faunal unit of Uyeno (in press)	C-46949

Remarks

The Pedderi-parawebbi faunal unit also occurs in the lower part of the Hume Formation at Powell Creek, western District of Mackenzie (Uyeno, in press). There the unit occurs within the brachiopod "Schuchertella" adoceta Zone.

Conodont Color Alteration Index (CAI) = 4½.

Depth and Stratigraphy	Conodonts and age	GSC Loc.
4625-4627.5 ft (1531.6-1532.3 m) Funeral Formation (464 g)	indeterminate conodont fragments only (2)	C-46949

Remarks

Conodont CAI = 6; conodonts from this interval suggest a high degree of metamorphism (Epstein et al., 1977).

The following intervals did not yield any conodonts:

Intervals	Weight of sample processed (g)
4598.5-4600.5 ft; 1401.6-1402.1 m	340
4627.5-4630.0 ft; 1410.4-1411.2 m	342
4710.0-4711.0 ft; 1435.6-1435.9 m	287
4726.0-4727.0 ft; 1440.5-1440.8 m	138
4856.0-4857.0 ft; 1480.1-1480.4 m	260
4866.0-4867.0 ft; 1483.1-1483.4 m	317
4875.0-4876.0 ft; 1485.9-1486.2 m	335

APPENDIX II

Report on 13 fossil lots from the Candex et al. Dahadinni M-43A well located at Latitude 63°52'59.3"N, Longitude 124°39'15.1"W, western District of Mackenzie (NTS 95N) by A.E.H. Pedder.

Depth and Stratigraphy	Fauna and age	GSC Loc.
3805 ft (1159.8 m) Hume Formation, Middle member	Radiastraea sp. cf. R. trichomisca (Crickmay) age: Middle Devonian, late Eifelian.	C-65089
3864 ft (1177.7 m) Hume Formation, Middle member	Alveolites sp. nov. age: Middle Devonian, Eifelian.	C-64521
3866 ft (1178.4 m) Hume Formation, Middle member	Digonophyllum sp. cf. D. powellense age: Middle Devonian, probably late Eifelian.	C-64523
3878 ft (1182.0 m) Hume Formation, Middle member	Radiastraea trichomisca (Crickmay) age: Middle Devonian, Late Eifelian.	C-64525
3881 ft (1182.9 m) Hume Formation, Middle member	Lekanophyllum? sp. indet. age: Early or Middle Devonian.	C-64524
3988 ft (1215.5 m) Hume Formation, Lower member	Tikhinella sp. indet. Stachyodes sp. indet. Thamnopora sp. indet. rugose coral, indet. fragment gastropods ostracodes age: Middle or Late Devonian.	C-65094
4002 ft (1219.8 m) Hume Formation, Lower member	Pachyfavosites sp. undet. age: Early or Middle Devonian.	C-65090
4009.5 ft (1221.1 m) Hume Formation, Lower member	Temnophyllum sp. indet. gastropods, indet. age: Middle or Late Devonian (not Famennian).	C-65088
4020 ft (1225.3 m) Hume Formation, Lower member	Alveolites sp. nov. age: Middle Devonian, Eifelian.	C-65092
4048 ft (1233.8 m) Hume Formation, Lower member	Alveolites? sp. age: Devonian?	C-65091
4314 ft (1314.9 m) Funeral Formation, Pellet Limestone member	gastropods age: not determinable.	C-65096

Depth and Stratigraphy	Fauna and age	GSC Loc.
4413 ft (1343.1 m) Funeral Formation, Pellet Limestone member	tabulate coral, gen. nov. (Multithecoporidae) age: Probably Middle Devonian.	C-65095
4986 ft (1519.7 m) Bear Rock Formation, Dolomitic member	Chovanella burgessi Peck and Eyer age: Middle Devonian.	C-65093

Remarks

Although the specimen of Radiastrea in GSC loc. C-65089 cannot be firmly identified, both it and R. trichomisca (Crickmay) in C-64525 should be considered diagnostic of the Hume Formation (adoceta and lower dysmorphostrota Zones of Pedder, 1975). Species that a decade or so ago would have been accommodated in Alveolites or Caliapora have recently been assigned to a number of new genera (Mironova, 1974). In the light of Mironova's and other work, the forms identified as Alveolites in C-64521 and C-65092 may belong to another genus. Regardless of this possibility, the species, which has not been named, is typical of the Hume Formation. Firm identification of the large cystomorph corals in C-64523 and C-64524 is impossible, because only incomplete specimens were recovered from the small diameter core. The occurrence of the foraminifer genus Tikhinella in C-65094 is important; previously it was regarded as being highly characteristic, if not entirely diagnostic, of the Upper Devonian Frasnian Stage (Toomey et al., 1970). The new tabulate coral in C-65095 is probably related to both Syringoporella and Spiroclados and, therefore, should be of Middle Devonian age. Rice (1971, p. 10) gave the range of the charophyte species Chovanella burgessi as late Eifelian to late Givetian. However, the occurrence in the Bear Rock Formation at a depth of 4986 feet (1519.7 m) (C-65093) is possibly early or middle, rather than late Eifelian.