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A REVIEW OF CRETACEOUS AND TERTIARY STRATIGRAPHY IN THE NORTHERN YUKON AND ADJACENT NORTHWEST TERRITORIES

Abstract

Cretaceous strata are widely exposed in the northern Yukon and adjacent Northwest Territories, whereas Tertiary to Holocene strata tend to be limited to the Yukon coastal plain, northernmost Richardson Mountains and adjacent to the Mackenzie Delta. However, under Mackenzie Delta and the Beaufort Sea continental shelf there are 14 to 16 km of Upper Cretaceous to Holocene strata, the bulk of which is Tertiary. The succession is characterized by a series of transgressive-regressive depositional cycles, which at the basin margins consist of alternating shale- and sandstone-dominant formations. Many of the sandstone-dominant successions can be traced basinward into shale-equivalent facies. Marine strata are prevalent in the sandstone-rich Lower Cretaceous formations, while Upper Cretaceous and Tertiary strata tend to contain more extensive fluviodeltaic sediments.

Three phases of tectonic development are reflected in the Cretaceous–Tertiary stratigraphic record, each phase of sedimentation beginning at a major regional unconformity or transgression. Each unconformity-bounded assemblage was deposited during a period dominated by extension or compression, or a combination of the two.

The oldest assemblage includes strata up to the early Aptian, during which extensional tectonics associated with rifting in the proto-Canada Basin was dominant. Epicontinental sedimentation prevailed and was characterized by the deposition of mature quartz arenites derived from the east and southeast. A southwest trending basin margin extended from the Tuktoyaktuk Peninsula area through the northern Richardson Mountains and across the northern edge of Eagle Plain, at the western end of which it appears to have swung south, paralleling the Ogilvie Mountain trend. A belt of sand-rich sediment formed along the basin margin, grading northwestward into shelf mud. Limited periods of basin expansion extended the basin margin to the southeast and south; for example, during the late Hauterivian and Barremian.

The second tectonic phase includes upper Aptian and Albian strata. During the Albian, extension still prevailed in the northern areas and helped create deep-water troughs on the oceanward side of the Eskimo Lakes Uplift, through the Blow River area and into the northern Keele Range and Kandik Basin. These Albian troughs have been called the Kugmallit, Blow, Keele, and Kandik troughs respectively. Although extensional tectonics was still a major force, Cordilleran compression began to influence sedimentation. The Blow, Keele and Kandik troughs appear to have been filled from a westerly to southwesterly provenance, an area that was part of the Brooks Range compressional foldbelt. In the Canadian part of the Cordillera, a shallow foreland trough was developing in the Peel Plateau area (Peel Trough) and marine shelf sediments, derived from the south, were being deposited.

By the end of the Albian, beginning of the Cenomanian, rifting in the proto-Canada Basin area had ceased, or at least subsided, and sea-floor spreading began in earnest. However, Cordilleran orogenesis began to increasingly impinge on the northen Yukon and is reflected in the development of a series of northward migrating foreland depocentres. From Cenomanian to about middle Maastrichtian time the foreland basin was on the North American craton, but, by the late Maastrichtian, sedimentation had become centred on the subsiding continental margin of Canada Basin.

Résumé

Les strates du Crétacé affleurent sur de vastes étendues dans le nord du Yukon et la partie contiguë des Territoires du Nord-Ouest, tandis que celles du Tertiaire-Holocène se limitent à la plaine côtière du Yukon, à l'extrême nord des monts Richardson et à la partie adjacente du delta du Mackenzie. Toutefois, sous la plate-forme continentale du delta du Mackenzie et de la mer de Beaufort, il existe entre 14 et 16 km de strates qui s'échelonnent du Crétacé supérieur à l'Holocène, mais dont la plupart datent du Tertiaire. La succession comporte une série de cycles sédimentaires de transgression-régression qui, en bordure du bassin, se caractérisent par l'alternance des formations à prédominance de shale ou de grès. Bon nombre des successions gréseuses passent en direction du bassin à des faciès équivalant à des shales. Les formations gréseuses du Crétacé inférieur contiennent des strates marines abondantes, tandis que les strates du Crétacé supérieur et du Tertiaire contiennent généralement des sédiments fluviodeltaïques plus étendus.

Les dépôts du Crétacé-Tertiaire témoignent de trois phases d'évolution tectonique, chaque phase de sédimentation ayant commencé à une discordance ou transgression régionale majeure. Chaque assemblage limité par des discordances s'est accumulé au cours d'une période où prédominait la distension, la compression ou une combinaison des deux.

L'assemblage le plus ancien comprend des strates qui remontent au début de l'Aptien, lorsque prédominait la tectonique de distension associée au rifting dans le proto-bassin Canada. La sédimentation épicontinentale y prévalait et s'est caractérisée par la mise en place de quartzites sédimentaires matures dont la source se trouvait à l'est et au sud-est. Une marge de bassin à orientation sud-ouest se prolongeait à partir de la péninsule de Tuktoyaktuk à travers le nord des monts Richardson et le bord septentrional de la plaine d'Eagle; à l'extrémité ouest de la plaine, elle semble s'être détournée vers le sud, parallèlement au mont Ogilvie. Une zone de sédiments sableux formée en bordure du bassin passe progressivement vers le nord-ouest en boue épicontinentale. Au cours de périodes limitées d'expansion du bassin, par exemple à la fin du Hauterivien et au Barrémien, la marge du bassin s'est prolongée vers le sud-est et le sud.

La deuxième phase tectonique a touché des strates de la partie supérieure de l'Aptien et de l'Albien. Au cours de l'Albien, la distension a continué de prédominer dans les zones septentrionales et a contribué à la création de fosses d'eau profonde sur le côté océanique du soulèvement des lacs Eskimo, dans la région de la rivière Blow et jusque dans la partie nord du chaînon Keele et du bassin de Kandik. Ces fosses albiennes sont appelées «cuvette Kugmallit», «cuvette de Blow», «cuvette de Keele» et «cuvette de Kandik», respectivement. Bien que la tectonique de distension soit demeurée importante, les effets de la compression cordillérienne ont commencé à se faire sentir au niveau de la sédimentation. Les sédiments qui ont rempli la cuvette de Keele, la cuvette de Blow et la cuvette de Kandic sont vraisemblablement venus de l'ouest ou du sud-ouest, région qui faisait partie de la zone de plissement par compression de Brooks Range. Dans la Cordillère du Canada, il y a eu formation d'une cuvette d'avant-pays peu profonde à proximité du plateau de Peel (cuvette de Peel) et accumulation de sédiments épicontinentaux dérivés du sud.

À la fin de l'Albien et au début du Cénomanien, le rifting avait cessé ou ralenti dans la région du proto-bassin Canada, et l'expansion océanique avait commencé. Toutefois, l'orogenèse de la Cordillère a commencé à toucher d'avantage le nord du Yukon, ce dont témoigne la création, dans l'avant-pays, d'une série de centres de sédimentation maximum qui se déplaçaient vers le nord. Du Cénomanien jusque vers le Maastrichtien moyen, le bassin de l'avant-pays se situait dans le craton nord-américain mais, dès la fin du Maastrichtien, le foyer de la sédimentation se trouvait sur la marge continentale subsidente du bassin Canada.

Summary

The study area encompasses that of the Operation Porcupine map area (Norris, 1985a), extending from about latitude 65°N to the Beaufort Sea and from longitude 132°W to the Alaska border. Within this area, Cretaceous strata are widely exposed in the northern Richardson, northern Ogilvie and British mountains, and are present in the subsurface under Mackenzie Delta and the Tuktoyaktuk Peninsula. Tertiary strata are not as well exposed and are present in the Caribou Hills east of Mackenzie Delta, and at scattered locales along the Yukon coastal plain and northernmost Richardson Mountains. Some Tertiary strata are present in Old Crow and Bonnet Plume basins, but are poorly exposed. The bulk of Tertiary strata are under Mackenzie Delta and the Beaufort Sea.

Throughout most of the area, Cretaceous to Tertiary strata consist of alternating sandstone- and shale-dominant formations, with thick shale successions representing more basinward locales. Lower Berriasian strata are represented principally by the shale-rich, shelf deposit of the upper Husky Formation, although a local, nearshore, sandy facies is present in part of the North Branch Formation. Husky shales are gradationally succeeeded by the sandstone-dominant, upper Berriasian Martin Creek Formation. At the basin margin, Martin Creek strata consist of shoreface and nearshore deposits dominated by storm produced sedimentary structures. Martin Creek strata become progressively shalier to the northwest, so that in the British Mountains the equivalent strata are shales of the Kingak Formation.

Valanginian strata include the shale-dominant McGuire Formation which rests abruptly to erosionally on older beds. West of Rapid Depression, McGuire strata cannot be mapped as a separate formation but become part of the Kingak Formation. Gradationally overlying the McGuire Formation are sandstones of the Kamik Formation. Kamik strata can be subdivided into a sandstone-rich lower member and a sandstone-shale upper member. The Lower member contains nonmarine and marginal marine beds under Mackenzie Delta and in the northeastern Richardson Mountains, but becomes marine to the west and southwest. Upper Kamik strata are everywhere marine, although marginal marine beds are present under Mackenzie Delta and in parts of the northern Ogilvie Mountains. Kamik strata probably are as young as middle Hauterivian, and possibly even late Hauterivian.

A major unconformity is present at the base of the next unit, the Mount Goodenough Formation. These strata are late Hauterivian to Barremian in age and are predominantly shale and siltstone deposited on a marine shelf. Sandstone beds are present locally at the base of the unit, especially on or adjacent to tectonic highs. Rat River strata gradationally overlie Mount Goodenough beds, although in the Stony River/Rat River areas they appear to be laterally equivalent, in part. Rat River strata are late Barremian to early Aptian in age and consist of interbedded sandstone and shale, commonly arranged in coarsening-upward cycles. These cycles contain shoreface and nearshore sediments that are dominated by storm produced sedimentary structures. Under Tuktoyaktuk Peninsula there is a local sandstone and conglomerate formation – the Atkinson Point Formation – that appears to be equivalent to both the Mount Goodenough and Rat River formations. Atkinson Point strata have been interpreted as representing fan-delta and nearshore sediments.

Abruptly to erosionally overlying early Aptian or older strata are a variety of late Aptian to Albian formations. In the Peel River, Stony River and Tuktoyaktuk Peninsula areas, late Aptian/Albian strata are represented by the Martin House and Arctic Red formations. The Martin House is identifed only on the plateau east of the Richardson Mountains and consists of interbedded shale, siltstone and sandstone. These beds represent a transgressive facies of marine shelf origin. Arctic Red strata are predominantly shale and are marine shelf deposits for the most part, although there are slope and basinal deposits under parts of Tuktoyaktuk Peninsula.

On the northwest flanks of the Richardson Mountains there are local occurrences of phosphatic ironstone, interbedded with shale and minor conglomerate and sandstone, that belong to the Lower Albian Rapid Creek Formation. These pass laterally westward, in the Blow River area, into the informally named Albian flysch, which contains interbedded shale, sandstone and conglomerate of sediment gravity-flow origin. On the northern edge of Eagle Plain and in the Kandik River areas, similar sediment gravity-flow deposits are present in the Sharp Mountain and Kathul formations respectively. In the Bell River area and under most of Eagle Plain, equivalent strata belong to the Whitestone River Formation, a shale-dominant unit that contains thin silty and sandy turbidites in its northern occurrences, but becomes more shelf-like in character along southern Eagle Plain.

A regional unconformity separates Lower Cretaceous from Upper Cretaceous strata. The bulk of known Upper Cretaceous strata are present under Eagle Plain where the Parkin, Fishing Branch, Burnthill Creek, and Cody Creek formations form the Eagle Plain Group. Parkin Formation strata consist of marine shale, with a basal transgressive sandstone. Fishing Branch sandstones gradationally overlie Parkin rocks and consist of nearshore to shoreline deposits. Burnthill Creek shales abruptly overlie Fishing Branch strata and are gradationally succeeded by sandstones and shales of the Cody Creek Formation. Together the Burnthill Creek and Cody Creek formations form an overall prograding succession, with marine beds of the Burnthill Creek Formation succeeded by nonmarine beds of the Cody Creek Formation in southern Eagle Plain, and by marine beds in northern Eagle Plain. Southwest of Eagle Plain, in the headwaters of Ogilvie River, are strata of the Monster Formation. The Monster Formation consists of predominantly nonmarine and nearshore sandstones and conglomerates, although there is a basal marine shale interval. To the southeast of Eagle Plain, in Bonnet Plume Basin, part of the Bonnet Plume Formation contains Upper Cretaceous fluvial sandstones and conglomerates. North of Eagle Plain, along the Porcupine River, are numerous fault bounded outliers of Upper Cretaceous marine strata. Along the Yukon coastal plain and in the subsurface under Mackenzie Delta and Tuktoyaktuk Peninsula, organic-rich shales of the Boundary Creek and Smoking Hills formations are the outer shelf to slope equivalents of the Eagle Plain Group.

A major shift in the locus of sedimentation occurred in the late Maastrichtian, when depocentres switched from the craton to the continental margin under the Beaufort Sea. Since late Maastrichtian time the bulk of sedimentation has been dominated by large delta complexes on the continental margin. Successive transgressive–regressive phases have produced an alternation of sandstone-rich and shale-rich successions at the basin margin, which have been given formational rank; these are: Tent Island Formation (shale), Moose Channel Formation (sandstone, with an upper shale member, the Ministicoog Member), Reindeer Formation (sandstone), Richards Formation (shale), Kugmallit Formation (sandstone), Mackenzie Bay Formation (shale), Akpak Sequence (shale), and Iperk Group (sandstone and shale). Basinward, this lithological differentiation becomes impossible because the sandstone-dominant intervals begin to shale-out.

Berriasian to Holocene sedimentation was influenced by three phases of tectonic activity. From Berriasian to early Aptian time extensional tectonics were prevalent and a series of uplifts and grabens/half grabens were extant in the area. Sediment was supplied from the east and southeast, off the craton, and the sandstones are typically quartz arenites. During the late Aptian and Albian the influence of Cordilleran orogenesis began to impinge on the area, although a major phase of extension created major basinal troughs in northern Yukon and along the northwestern flank of Tuktoyaktuk Peninsula. Sediment began to be shed from tectonic uplands to the west and south, and litharenite sandstones became a prevalent lithotype. Thick flysch deposits accumulated in the troughs, which were filled by the end of the Albian. Since the Cenomanian, compression has been the dominant tectonic force and sedimentation has been characterized by a series of northward migrating depocentres as part of the Cordilleran foreland basin. Sandstones are mostly litharenites, derived from the Cordillera to the south and southwest. A late Miocene unconformity in the Beaufort Sea succession separates folded strata below from essentially undeformed strata above, marking a major tectono-stratigraphic boundary. However, in northeastern Alaska and parts of the Canadian western Beaufort, Plio-Pleistocene strata are involved in younger folds.

Sommaire

La région à l'étude englobe la région cartographique visée par l'Opération Porcupine (Norris, 1985a), qui s'étend d'environ 65° de latitude N jusqu'à la mer de Beaufort, et de 132° de longitude W jusqu'à la frontière de l'Alaska. Dans cette région, les strates du Crétacé affleurent sur de vastes étendues dans le nord des monts Richardson et Ogilvie et dans les monts British, et elles se rencontrent aussi dans la subsurface du delta du Mackenzie et de la péninsule de Tuktoyaktuk. Les strates du Tertiaire sont moins visibles et se rencontrent dans les collines Cariboo à l'est du delta du Mackenzie et, sporadiquement, le long de la plaine côtière du Yukon et dans l'extrême nord des monts Richardson. Quelques strates du Tertiaire se rencontrent dans les bassins d'Old Crow et de Bonnet Plume, mais elles sont peu visibles. La plupart des strates du Tertiaire se trouvent sous le delta du Mackenzie et la mer de Beaufort.

Dans la plus grande partie de la région, les strates qui s'échelonnent du Crétacé au Tertiaire se caractérisent par l'alternance des formations à prédominance de grès ou de shale; les successions épaisses de shale représentent des endroits plus près du bassin. Le dépôt épicontinental, riche en shale, de la partie supérieure de la Formation de Husky représente les principaux sédiments du Berriasien inférieur, bien qu'un faciès sableux, local, littoral, soit présent dans une partie de la Formation de North Branch. Les shales de Husky passent progressivement à la Formation de Martin Creek à prédominance de grès, de la partie supérieure du Berriasien. En bordure du bassin, les strates de Martin Creek se composent de dépôts de zone littorale et d'avant-plage, où dominent des structures sédimentaires de tempête. La teneur en shale des strates de Martin Creek augmente vers le nord-ouest, de sorte que dans les monts British, les strates équivalentes sont des shales de la Formation de Kingak.

Les strates du Valanginien comprennent la Formation de McGuire à prédominance de shale, qui est séparée des lits sous-jacents plus anciens par un contact abrupt ou d'érosion. À l'ouest de la dépression de Rapid, il est impossible de cartographier les strates de McGuire comme une formation distincte; en effet, à cet endroit, ces couches font partie de la Formation de Kingak. Un contact progressif sépare la Formation de McGuire des grès susjacents de la Formation de Kamik. Les strates de Kamik se subdivisent en un membre inférieur, riche en grès, et en un membre supérieur, de grès et de shale. Le membre inférieur contient des couches margino-marines et non marines sous le delta du Mackenzie et dans le nord-est des monts Richardson, mais ces couches se transforment en couches marines vers l'ouest et le sud-ouest. Les strates du membre supérieur de Kamik sont partout d'origine marine, bien que des lits margino-marins soient présents sous le delta du Mackenzie et par endroits dans le nord des monts Ogilvie. Les strates de Kamik ne remontent vraisemblablement qu'au Hauterivien moyen, et possiblement à la fin du Hauterivien.

Une discordance majeure existe sous la base de l'unité suivante, la Formation de Mount Goodenough. Ces strates s'échelonnent de la fin du Hauterivien au Barrémien et se composent principalement de shale et de siltstone mis en place sur une plate-forme continentale. Des couches de grès se rencontrent par endroits à la base de l'unité, notamment sur les hauteurs tectoniques ou à proximité. Un contact progressif sépare les strates de Rat River des couches sous-jacentes de Mount Goodenough, bien que dans la région des rivières Stony et Rat, elles semblent en être en partie latéralement équivalentes. Les strates de Rat River s'échelonnent de la fin du Barrémien au début de l'Aptien et se composent de grès et de shale interstratifiés, souvent disposés en séquences négatives dans lesquelles se trouvent des sédiments de zone littorale et d'avant-plage où dominent des structures sédimentaires de tempête. Sous la péninsule de Tuktoyaktuk, il existe une formation locale de grès et de conglomérat, la Formation d'Atkinson Point, qui semble être équivalente à la fois à la Formation de Mount Goodenough et à la Formation de Rat River. Les strates de la Formation d'Atkinson Point représentent vraisemblablement des sédiments de cône deltaïque et de zone littorale.

Un contact abrupt ou d'érosion sépare une gamme de formations qui s'échelonnent de la fin de l'Aptien à l'Albien, des strates sous-jacentes du début de l'Aptien ou plus anciennes. À proximité de la rivière Peel, de la rivière Stony et de la péninsule de Tuktoyaktuk, les formations de Martin House et d'Arctic Red remontent à la fin de l'Aptien et à l'Albien. La Formation de Martin House se rencontre uniquement sur le plateau à l'est des monts Richardson; elle se compose de shale, de siltstone et de grès interstratifiés. Ces couches représentent un faciès transgressif d'origine épicontinentale. Les strates de la Formation d'Arctic Red se composent principalement de shale et proviennent pour la plupart d'une plate-forme continentale, bien qu'il existe des dépôts de talus et de bassin à certains endroits sous la péninsule de Tuktoyaktuk.

Sur les flancs nord-ouest des monts Richardson, il existe des manifestations locales de roche ferrugineuse phosphatique, interstratifiée de shale et de petites quantités de conglomérat et de grès, de la Formation de Rapid Creek qui remonte à l'Albien inférieur. Ces sédiments se transforment latéralement vers l'ouest, dans la région de la rivière Blow, en un flysch albien auquel on a donné un nom informel, qui contient une interstratification de shale, de grès et de conglomérat mis en place par des coulées gravitaires. Des sédiments semblables, d'origine comparable, se rencontrent dans la Formation de Sharp Mountain, sur la marge nord de la plaine d'Eagle, et dans la Formation de Kathul, dans la région de la rivière Kandik. À proximité de la rivière Bell et sous la plus grande partie de la plaine d'Eagle, les strates équivalentes appartiennent à la Formation de Whitestone River, unité à prédominance de shale qui contient des turbidites silteuses et sableuses peu épaisses dans le nord, mais dont la nature devient plus épicontinentale le long de la partie sud de la plaine d'Eagle.

Une discordance régionale sépare les strates du Crétacé inférieur et celles du Crétacé supérieur. La plupart des strates connues du Crétacé supérieur se trouvent sous la plaine d'Eagle, où les formations de Parkin, de Fishing Branch, de Burnthill Creek et de Cody Creek constituent le Groupe d'Eagle Plain. La Formation de Parkin se compose de shale marin, avec un grès transgressif à la base. Un contact progressif sépare les grès de la Formation de Fishing Branch, qui sont des dépôts de zone littorale ou de ligne de rivage, des roches sous-jacentes de Parkin. Les shales de Burnthill Creek sont séparés des strates sous-jacentes de Fishing Branch par un contact abrupt et passent progressivement aux grès et shales de la Formation de Cody Creek. Ensemble, les formations de Burnthill Creek et de Cody Creek représentent une succession progradante, les lits marins de la Formation de Burnthill Creek étant suivis de lits non marins de la Formation de Cody Creek dans le sud de la plaine d'Eagle, et de lits marins dans le nord de la plaine. Des strates de la Formation de Monster se trouvent au sud-ouest de la plaine d'Eagle, à l'emplacement de la source de la rivière Ogilvie; ces strates se composent principalement de grès et de conglomérats non marins et littoraux, bien qu'il existe un intervalle de shale marin à la base. Au sud-est de la plaine d'Eagle, dans le bassin de Bonnet Plume, une partie de la Formation de Bonnet Plume contient des grès et des conglomérats fluviatiles du Crétacé supérieur. Au nord de la plaine d'Eagle, le long de la rivière Porcupine, il existe de nombreuses avant-buttes limitées par des failles qui se composent de strates marines du Crétacé supérieur. Le long de la plaine côtière du Yukon et dans la subsurface sous le delta du Mackenzie et la péninsule de Tuktoyaktuk, les shales riches en matières organiques des formations de Boundary Creek et de Smoking Hills sont des sédiments qui équivalent au Groupe d'Eagle Plains, mais qui se sont accumulés sur une plate-forme externe ou une pente.

Un déplacement majeur du foyer de sédimentation s'est produit à la fin du Maastrichtien, lorsque les centres de sédimentation maximum ont passé du craton à la marge continentale sous la mer de Beaufort. Depuis la fin du Maastrichtien, la plus grande partie de la sédimentation se produit dans de vastes complexes deltaïques sur la marge continentale. Des phases successives de transgression-régression ont produit une alternance de successions riches en grès ou en shale en bordure du bassin; ces successions ont reçu le rang de formation : Formation de Tent Island (shale), Formation de Moose Channel (grès, avec un membre supérieur de shale, le Membre de Ministicoog), Formation de Reindeer (grès), Formation de Richards (shale), Formation de Kugmallit (grès), Formation de Mackenzie Bay (shale), Séquence d'Akpak (shale) et Groupe d'Iperk (grès et shale). Cette différenciation lithologique disparaît en direction du bassin, car les intervalles gréseux commencent à former un piège de faciès.

Trois phases d'activité tectonique ont influencé la sédimentation du Berriasien à l'Holocène. La tectonique de distension a prédominé du Berriasien au début de l'Aptien, et une série de soulèvements et de grabens et demi-grabens se sont formés dans la région. La source des sédiments se trouvait à l'est et au sud-est, sur le craton, et les grès sont typiquement des quartzites sédimentaires. Au cours de la fin de l'Aptien et de l'Albien, les effets de l'orogenèse de la Cordillère ont commencé à se faire sentir dans la région, bien qu'une phase majeure de distension ait créé d'importantes cuvettes de bassin dans le nord du Yukon et le long du flanc nord-ouest de la péninsule de Tuktoyaktuk. Les hautes terres tectoniques à l'ouest et au sud ont commencé à fournir des sédiments, et les litharénites sont devenues un des lithotypes majeurs. Des flyschs épais se sont accumulés dans les cuvettes, qui étaient comblées à la fin de l'Albien. Depuis le Cénomanien, la compression est devenue la force tectonique prédominante et la sédimentation a lieu dans une série de centres de sédimentation maximum qui se déplacent vers le nord et qui font partie du bassin de l'avant-pays de la Cordillère. Les grès sont principalement des litharénites en provenance de la Cordillère au sud et au sud-ouest. Une discordance datant de la fin du Miocène se trouve dans la succession de la mer de Beaufort et sépare les strates plissées des strates susjacentes, essentiellement intactes; elle constitue une importante limite tectonostratigraphique. Toutefois, dans le nord-est de l'Alaska et à certains endroits dans la partie ouest, en territoire canadien, de la mer de Beaufort, les plis plus jeunes ont déformé des strates plio-pléistocènes.

INTRODUCTION

No single body of text is available which deals with the Cretaceous to Holocene stratigraphy of northern Yukon and adjacent Northwest Territories in a comprehensive manner. Data are scattered in numerous publications, the most relevant covering a span of approximately 32 years. Consequently, this presentation is intended to be a reference source for the basic descriptions, age determinations, and depositional interpretations of Cretaceous and Tertiary stratigraphic units in the northern Yukon and adjacent Northwest Territories. However, to complete the stratigraphic picture for the Beaufort shelf, Holocene strata are briefly described. The work is a compendium of the author's own observations and of previously published material. Some previously unpublished data, based on the author's own work (both field and subsurface studies), are included, as well as a summary of past work. However, interpretations of the data are the responsibility of the present author.

The study area covers the northern Yukon and adjacent Northwest Territories, from latitude 65°N, northward to the Beaufort Sea, and from longitude 132°W, westward to the Alaska border. This area encompasses the 1:500 000 scale map produced by Norris (1985a), who mapped the area under the Geological Survey's Operation Porcupine program. Cretaceous strata are widely exposed within the study area (Fig. 1), whereas Tertiary and Pleistocene strata are less well represented and are best examined from the exploration boreholes on Mackenzie Delta, Tuktoyaktuk Peninsula, the northernmost edge of the Richardson Mountains, and the Beaufort Sea (Figs. 2, 3). Although the bulk of data on Cretaceous geology comes from surface studies there is a considerable amount of data from the subsurface of the southern Mackenzie Delta and the Tuktoyaktuk Peninsula (Fig. 3), as well as Eagle Plain. To present a more complete picture of Cretaceous to Holocene geology, reference to strata outside the study area will be cited wherever appropriate.

Lower Cretaceous strata are widely exposed, and are present in the British Mountains, northern Richardson Mountains, Keele Range, northern Ogilvie Mountains, and underlying much of Peel Plateau. Upper Cretaceous strata are less extensively exposed, the largest single area of occurrence is under Eagle Plain and adjacent Bell Basin. Other areas of outcrop include: adjacent to the Tatonduk River (westernmost Ogilvie Mountains); isolated, fault-bounded outcrops on the banks of Porcupine River in the Old Crow Basin; the Bonnet Plume Basin; the northern Richardson Mountains; between Stony River and Rat River; the northernmost part of the Richardson Mountains; scattered outcrops along the Arctic coastal plain of the Yukon; and river-bank outcrops east and north of Inuvik. Cenozoic strata are the least well exposed, and are present only in the Bonnet Plume Basin; the northernmost Richardson Mountains; along the Yukon coastal plain; and the Caribou and Storm hills east of the Mackenzie Delta. Some Tertiary strata are present in the Old Crow Basin, but detailed descriptions of their lithology and stratigraphy are lacking.

Previous work

Although some of the earliest scientific investigations in the area noted the presence of Mesozoic and Cenozoic strata, very little detailed stratigraphic or structural work was available until members of the Geological Survey began systematic surveys, beginning in the mid 1950s. Jeletzky (1958) began by publishing reports on the Jurassic and Cretaceous rocks from the Aklavik Range, northern Richardson Mountains. Subsequent publications by Jeletzky (1960, 1961, 1967, 1971a, b, 1972, 1974, 1975a, b, 1980) dealt principally with Jurassic and Lower Cretaceous stratigraphy and biostratigraphy. His work resulted in a number of informal and formal stratigraphic divisions for Jurassic and Lower Cretaceous rocks and a biostratigraphic zonation of the same strata (Appendix 1; references to biostratigraphic work, in addition to those listed above, include 1964, 1973, 1984). Many of the Lower Cretaceous formations were to be named by Jeletzky. As he was unable to complete this objective prior to his death in 1988, a posthumously co-authored publication was produced to formalize the units (Dixon and Jeletzky, 1991).

Norris et al. (1963) published one of the first comprehensive geological maps of the study area, on a 1:1 million scale, on which the regional distribution of Mesozoic and Cenozoic strata was shown. Subsequent maps, at 1:250 000 scale (Norris, 1981a-1, 1982a-d), are more detailed and Norris (1985a) later condensed this detailed mapping data on to a 1:500 000 scale map.

Most of the reconnaissance and detailed stratigraphic studies published to date have been for limited areas, or specific strata. Mountjoy (1967) presented some preliminary stratigraphic studies of Upper Cretaceous and Tertiary strata for the Operation Porcupine area. Young (1971, 1972, 1973a, b, 1975a, b, 1977), Young et al. (1976), Young and

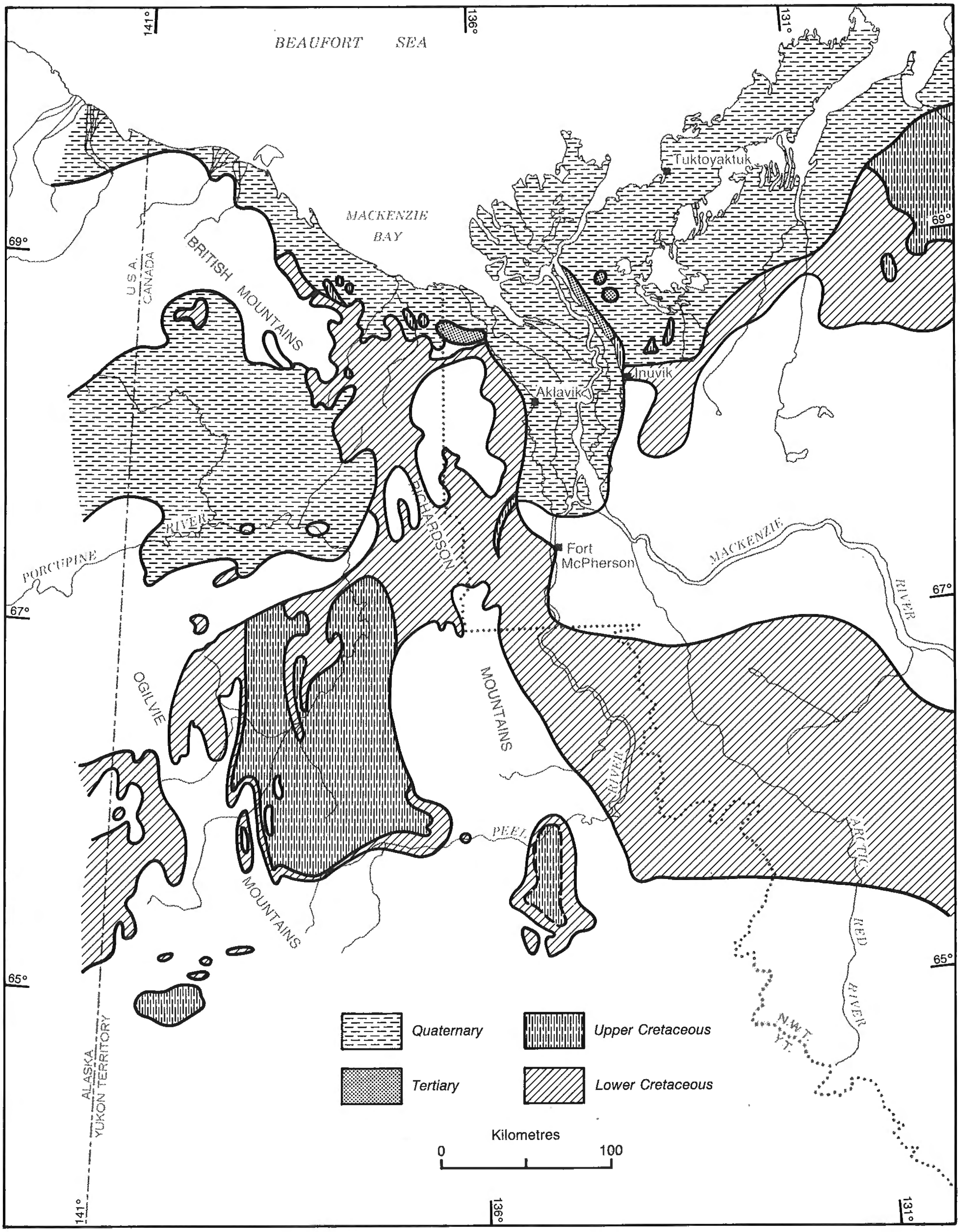

Figure 1. Distribution of Cretaceous to Quaternary strata. (Modified from Norris, 1985b.)

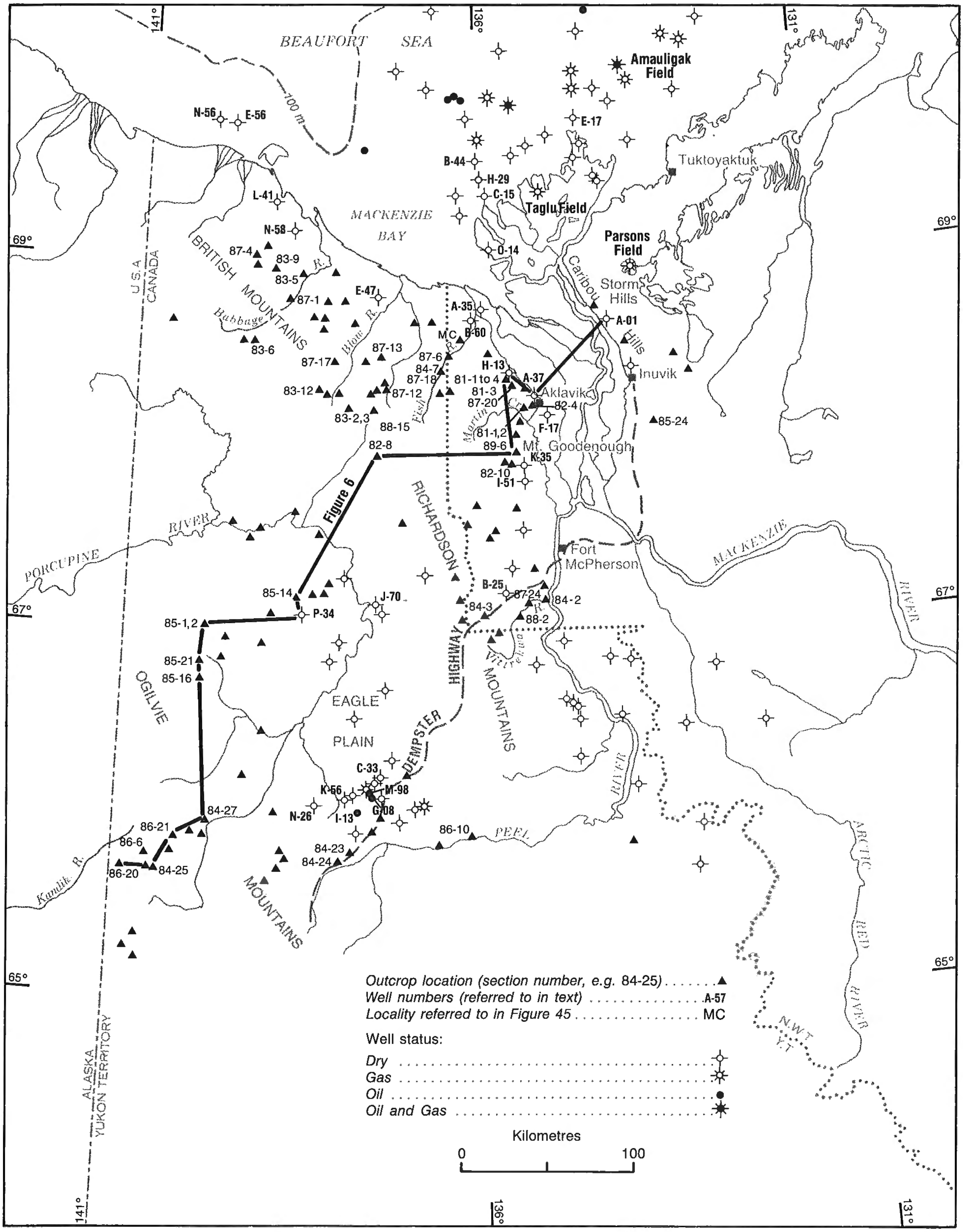

Figure 2. *Geographic names, location of wells, and surface sections visited by the author and the location of the log cross-section shown in Figure 6. (The sections are identified by year and section number – e.g. 82-5. Within the Geological Survey of Canada all survey officers are given a unique alphabetic code that precedes the section numbers, in Dixon's case all section numbers are preceded by DFA.)*

Robertson (1984), and Dixon (1982) concentrated their studies mostly on Cretaceous strata in the northern Yukon and Mackenzie Delta. Other significant local stratigraphic studies of Cretaceous rocks include works by Mountjoy and Chamney (1969), Norris and Hopkins (1977), Ricketts (1988), Dixon (1986a, 1987, in press a), and Dixon et al. (1989). Dixon (1991) described the Neocomian Parsons Group on a more regional basis.

Tertiary stratigraphy has been described by Holmes and Oliver (1973), Young (1975a), Young et al. (1976), Young and McNeil (1984), Hawkings and Hatlelid (1975), Price at al. (1980), Dietrich et al. (1985), and Dixon et al. (1985, in press). Holocene geology has been reported on by Mackay (1963) and Vilks et al. (1979).

Publications on areas immediately east of the Operation Porcupine study area, which are relevant to Cretaceous to Pleistocene geology, include those of Yorath and Cook (1981), and Aitken et al. (1982).

Regional syntheses have been written by Lerand (1973), Miall (1973), Balkwill et al. (1983), and Dixon (1986b).

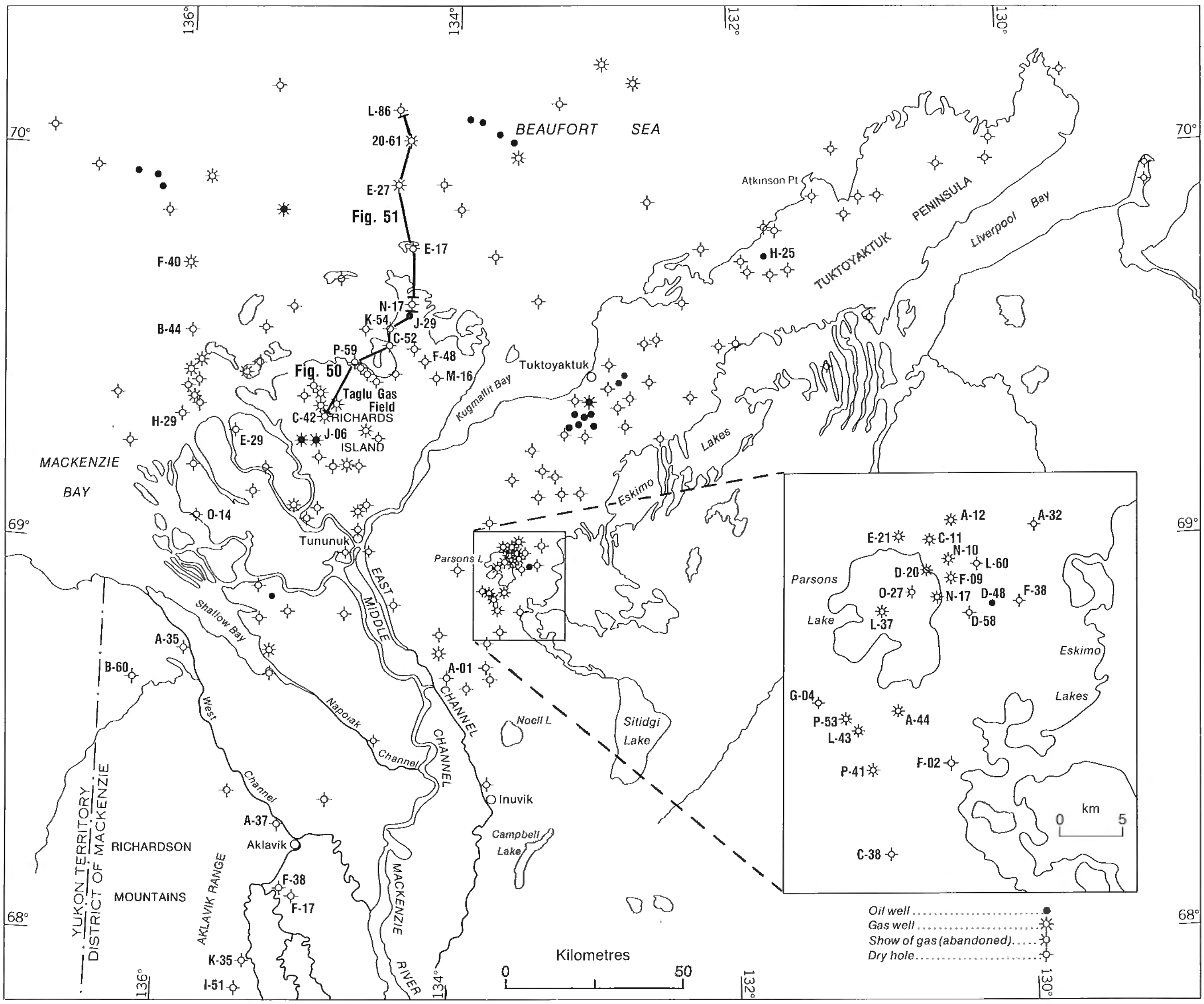

Figure 3. Well locations in the Mackenzie Delta, Tuktoyaktuk Peninsula, and nearshore areas, and the location of log cross-sections for Figures 50 and 51.

Geological setting

The study area contains four basic tectonic elements. The first occurs east of the Richardson Mountains, where the area is underlain by mildly deformed, westward to northwestward thickening, homoclinal, Paleozoic to Cenozoic strata of the North American interior platform. Underlying the platform wedge is a very thick Proterozic succession that appears to be more intensely deformed (Norris, 1985b; Cook et al., 1987). West of the platform homocline are more intensely deformed strata of the second element, the Cordilleran foldbelt. The foldbelt extends offshore under the western Beaufort Sea, but folding and faulting in the Upper Cretaceous/Tertiary section dies out to the northeast, offshore from the Tuktoyaktuk Peninsula (Dixon et al., 1985). Underlying Tuktoyaktuk Peninsula and the adjacent continental shelf is the transition zone between continental and oceanic crust, comprising the third element, the faulted continental margin. Two prominent fault zones occur in the faulted margin, the inner, Eskimo Lakes Fault Zone, and its offshore extension, and an outer hingeline (Dixon et al., 1985). North of the faulted margin is the fourth tectonic element, the oceanic crust, or transitional, crust.

In the western Beaufort Sea, Tertiary deformation has masked the older faulted continental margin. Within each of the four tectonic terranes local elements are identified on the basis of local structural style and internal stratigraphy (Fig. 4).

The Mesozoic to Tertiary succession reflects the evolution and interaction of the above tectonic elements, especially the opening of Canada Basin and the northward migration of the Cordilleran foldbelt (Dixon, in press b; Embry and Dixon, 1990). From at least Jurassic time until the early Aptian the northern Yukon/northern Alaska area was dominated by extension prior to the opening of Canada Basin. During the late Aptian to Albian, extensional tectonics was still active but compressional tectonics began to impinge on the northern Yukon. The main phase of drifting of the Canada Basin margins was from Cenomanian until probably late Maastrichtian time, or younger. Concurrent with drift, but also extending until at least late Miocene time, there was compression and possibly some strike-slip motion.

The change in tectonic regimes during the Cretaceous is apparent in the change from an east and southeastern provenance to a south and southwest provenance during the late Aptian/Albian. Since the late Miocene there has been minimal tectonic activity in the northwestern District of Mackenzie and eastern Beaufort Sea, although in northeastern Alaska and parts of the western Canadian Beaufort Sea, sediments as young as the Pleistocene are involved in folding and thrusting.

Acknowledgments

The reviews by A.P. Hamblin and D.H. McNeil were much appreciated and helped improve the text. Field data were collected over many years and I would like to thank my field assistants who helped during those years: B. Edwards, K. Hugo, K. McIvor, L. Velcic, L. Haid, and R. Peach. Polar Continental Shelf Project provided helicopter support during many of the field operations as well as casual charter from Sunrise Helicopters in Inuvik. The Western Arctic Scientific Resource Centre in Inuvik provided accommodation and some logistical support. Camp facilities were mostly organized by GSC personnel and I would like to thank L.S. Lane, D.W. Morrow and M.P. Cecile for setting up efficient and friendly camps. In 1985, the Archaeological Survey of Canada, under the leadership of J. Cinq-Mars, kindly shared their camp facilities near Old Crow. My understanding of Cretaceous–Tertiary geology of northwestern Canada has benefited greatly from the discussions and paleontological reports of several colleagues, notably D.J. McIntyre, D.H. McNeil, J. Jeletzky, and S. Fowler. Numerous discussions with petroleum industry personnel have also been beneficial and to these anonymous individuals I offer my thanks.

STRATIGRAPHY

Introduction

Cretaceous and Tertiary strata are virtually all siliciclastic rocks and the succession consists of alternating sandstone- and shale-dominant units, with some of the sandstone units grading laterally into shale. Formal stratigraphic names have been applied to most of the readily mapped and identifiable lithostratigraphic units (Fig. 5). Figure 5 illustrates the correlations and terminology adopted for this report. Reasons for some changes in correlations and terminology have been given by Dietrich et al. (1985) and Dixon (1986b), and some also will be discussed in the following text. Also shown on Figure 5 are the informal stratigraphic terms originally used and how they relate to the formal nomenclature. Figure 6 illustrates the lithology, thickness and correlations of Cretaceous/Tertiary units in the study area, and

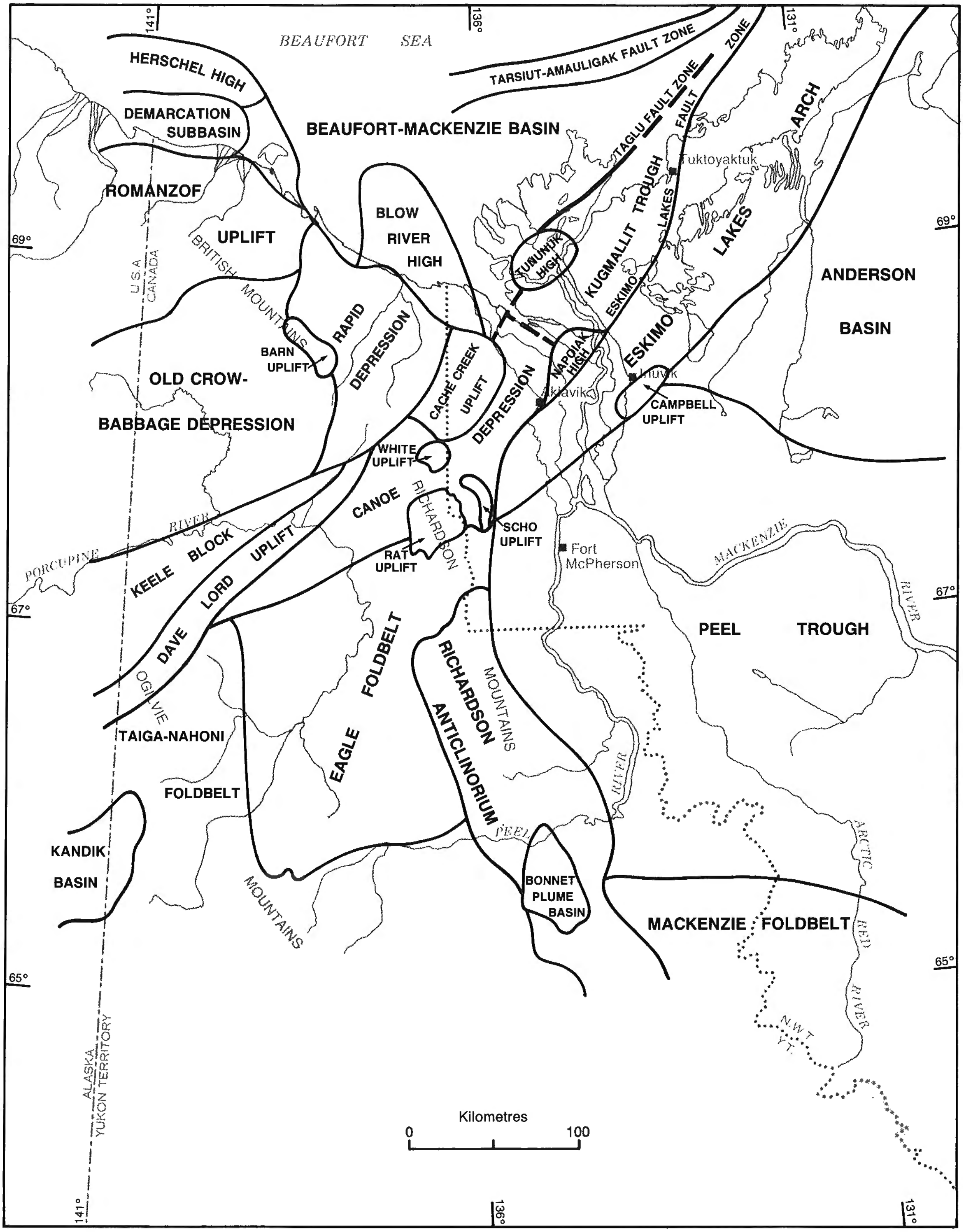

Figure 4. *Tectonic elements. (Modified from Norris, 1983; Yorath and Cook, 1981; and Dixon et al., 1985.)*

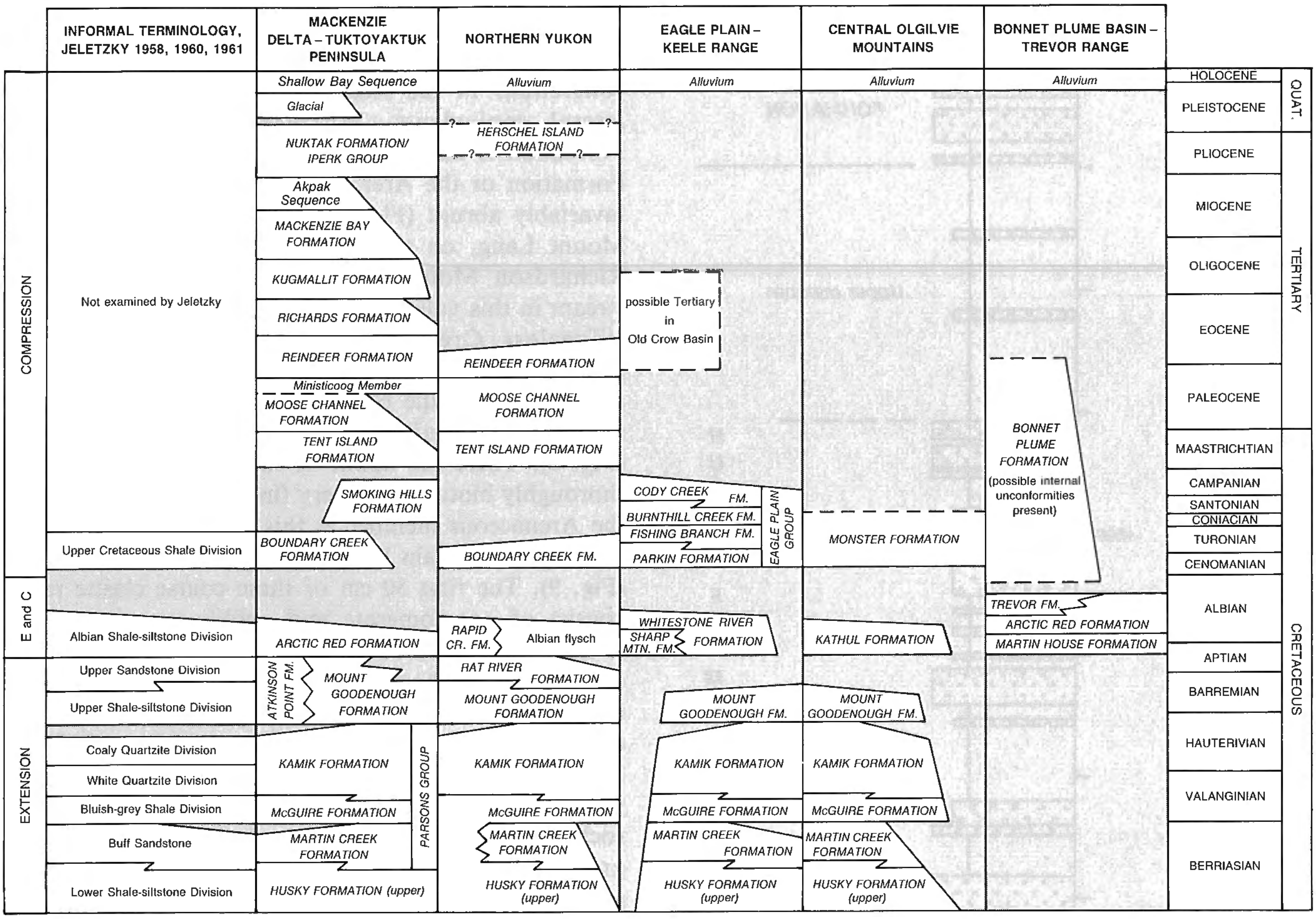

Figure 5. Correlation table.

identifies some of the more important unconformities in the succession.

Husky, North Branch, and Kingak formations

Description

The Husky Formation was defined by Jeletzky (1967) and was originally identified informally as the Lower shale-siltstone division (Jeletzky, 1958, 1960, 1961). In its type area of the Aklavik Range, northern Richardson Mountains, it is divisible into four informal members, which are, in ascending order: the Lower, Arenaceous, Red-weathering, and Upper members. Only the last two are Cretaceous in age. In the subsurface of Mackenzie Delta/Tuktoyaktuk Peninsula only two members are recognized, the "lower" and "upper" members (Figs. 6, 7) (Dixon, 1982; Braman, 1985). The subsurface Lower member is equivalent to Jeletzky's (op. cit.) Lower and Arenaceous members and the subsurface Upper member is equivalent to the Red-weathering and Upper members of Jeletzky (op. cit.).

In the vicinity of Vittrekwa River (Section 82-14; Fig. 2), strata laterally equivalent to the Husky Formation belong to the sandstone-dominant North Branch Formation, which extends at least into the Berriasian *Buchia okensis* Zone (Jeletzky, 1967). On the western slopes of the Richardson Mountains and in the Keele Range the sandstone-dominant Porcupine River Formation (Jeletzky, 1977) is laterally equivalent to the Lower and Arenaceous members of the Husky Formation. Abruptly overlying the Porcupine River sandstone is a shale succession that is equivalent to the Red-weathering and Upper members of the Husky Formation (Fig. 6). Norris (1981c, e, i) mapped this shale succession as Husky Formation. In the British Mountains, the Jurassic to Berriasian succession is shale-dominant and is part of the Kingak Formation. Jurassic and early Berriasian strata in the northern Ogilvie Mountains (between Sections 85-1 and 84-27; Fig. 2) contain Porcupine River and Husky equivalent

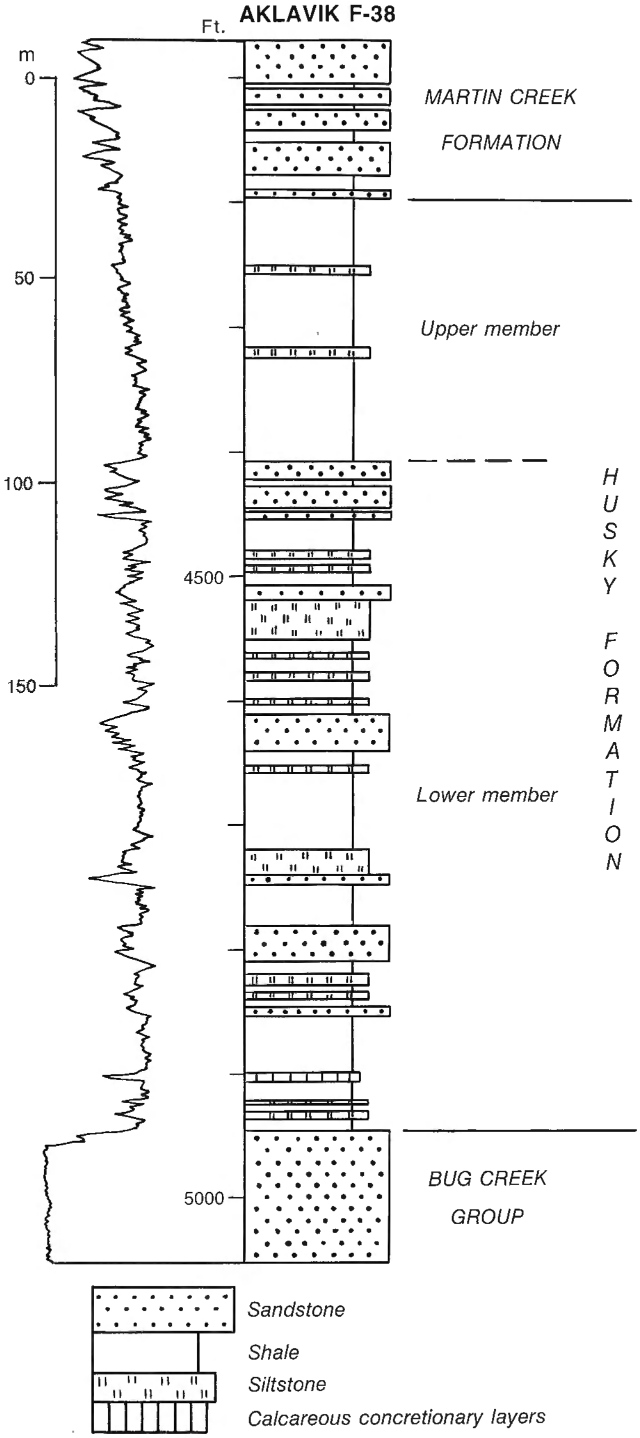

Figure 7. Lithology and gamma-ray log signature of the Husky Formation in the Aklavik F-38 well.

strata, but, south of Section 84-27, Jurassic and Berriasian strata have been eroded and Valanginian shale of the McGuire Formation rests on a truncated Jurassic section, or possibly a Permian shale (Sections 84-25 and 86-21; Fig. 6).

The Berriasian part of the Husky Formation is everywhere shale with thin interbeds of siltstone and sandstone in its uppermost part, and abundant concretions in the Red-weathering member and its lateral equivalents. Wherever the upper Husky Formation is underlain by either the Porcupine River Formation or the Arenaceous member, the contact is invariably abrupt (Figs. 7, 8). In the valley north of Mount Lang, on the eastern slopes of the northern Richardson Mountains (Section 82-10; Fig. 2; the stream in this valley has been informally refered to as "Treeless Creek" in a number of Jeletzky's publications), the Husky Formation outcrops extensively and the contact between the Arenacaeous and Red-weathering members is particularly clear (Fig. 8). There are about 40 m of argillaceous, silty, thoroughly bioturbated, very fine grained sandstone of the Arenaceous member at this locality, abruptly and erosionally overlain by 4.5 m of coarser clastic rocks (Fig. 9). The first 50 cm of these coarse clastic rocks consist of conglomerate and pebbly, coarse grained sandstone in which there are only a few traces of cross-stratification. The basal beds of the pebbly clastic rocks grade up into planar crossbedded, medium to coarse grained sandstone. Each crossbed set is 20 to 30 cm thick and the cross-strata dip to the north or northeast (Fig. 10). The upper 1 m of the coarse clastic rocks consist of 10 to 15 cm thick beds of medium grained, moderately to thoroughly bioturbated sandstone, commonly separated by shaly partings. These uppermost beds are abruptly overlain by shales of the Red-weathering member.

The Arenaceous and Red-weathering members have been dated by Jeletzky (1967) as latest Jurassic and Berriasian respectively, and the Jurassic/Cretaceous boundary is at, or close to, the contact between the two members. The vertical facies changes (described above) in the Arenaceous to Red-weathering members are interpreted as representing a significant transgressive event. It is probable that the coarse clastic rocks represent deposition during transgression, following a period of minor erosion. In the northern Ogilvie Mountains (Locality 85-21; Fig. 2) a red weathering, concretion-rich shale rests abruptly on Porcupine River sandstone. However, at this location there are no obvious transgressive beds between the shale and the sandstones, and the basal part of the red weathering shale apparently is slightly older (latest Tithonian; Jeletzky, pers. comm., 1985) than the red weathering shale in the Aklavik Range. The slight difference in age between strata at the two locations indicates that the transgression proceeded in a general easterly direction, an interpretation supported by the general facies patterns seen in Berriasian strata (Dixon, 1986b).

Figure 8. The Husky Formation at "Treeless Creek" (Section 82-10). 1 – Lower member, 2 – Arenaceous member, 3 – Red-weathering and Upper members. ISPG photo. 1895-4.

The post-Porcupine River Formation/Arenaceous member part of the Husky Formation attains thicknesses up to 100 m throughout most of its area of occurrence.

In the British Mountains, Jurassic to Valanginian strata are difficult to subdivide, owing to the dominance of shale throughout this part of the succession. Consequently, this entire interval is identified as the Kingak Formation, a stratigraphic term derived from Alaska (Leffingwell, 1919; Detterman et al., 1975). Although at some locales there are siltier parts in the succession, there is insufficient biostratigraphic control to identify any facies change near the Jurassic/Cretaceous boundary.

The Upper member of the Husky Formation tends to become siltier and sandier upsection, either as a component of the shales or as discrete, thin beds that are either bioturbated or finely laminated. Under the Mackenzie Delta/Tuktoyaktuk Peninsula the transition from Husky shale to overlying Martin Creek sandstone is gradational, from bioturbated silty-sandy mudstone of the Husky Formation into bioturbated, argillaceous, very fine grained sandstone of the Martin Creek Formation (Dixon, 1982). On the eastern slope of the northern Richardson Mountains the transition is more abrupt (Fig. 11), although still conformable. In the northern Ogilvie Mountains and western slopes of the northern Richardson Mountains a gradational contact is present, and the shale-dominant Husky Formation grades up into thinly interbedded shale and sandstone, in turn succeeded by the sandstone-rich Martin Creek Formation.

The North Branch Formation contains *Buchia okensis* in the upper part of the Sandstone-conglomerate member (Jeletzky, 1967), which indicates an equivalence with the Red-weathering member of the Husky Formation. The overlying Glauconitic sandstone member yielded no macrofossils and Jeletzky concluded that it was probably Berriasian and in continuity with the underlying *B. okensis*-bearing Berriasian strata. However, palynomorphs recovered from an interval near the base of the glauconite-bearing sandstones indicate a Barremian age (McIntyre, pers. comm., 1983). Therefore, some of the beds originally placed within the North Branch Formation are part of the basal arenaceous beds of the Mount Goodenough Formation, and a major unconformity occurs in what was originally defined as North Branch Formation. It is possible that Unit 38 (the base of the Glauconitic sandstone member) in the type section (Jeletzky, 1967, p. 133) could be the basal bed of the Mount Goodenough Formation, resting erosionally on North Branch strata. This revision of the stratigraphy requires that the North Branch Formation be restricted to include only Units 1 to 37 in Jeletzky's (op. cit., p. 132-137) original description of the type section. That part of the North Branch Formation equivalent to the upper Husky Formation includes at least Units 35 to 37 in the type section (op. cit.).

Depositional environment

The abundance of macro- and microfossils attests to the marine origin of the upper Husky Formation and equivalent strata. The argillaceous nature of these rocks, and the predominance of bioturbation in the silty and sandy beds, indicate a low-energy depositional environment. Also, the upper Husky beds are part of a progradational succession that includes the sandstone facies of the overlying Martin Creek Formation. The above cited features indicate deposition in a shelf environment, probably mid to outer shelf. Similarly, the Kingak Formation was deposited in a mid to outer shelf environment.

The Berriasian part of the North Branch Formation is in a coarser facies and the presence of marine fossils, hummocky cross-stratification (HCS), wave ripples, some planar crossbeds, and bioturbated beds indicate a generally high-energy setting. Deposition was on the inner shelf, probably close to the shoreline.

Figure 9. The Arenaceous member of the Husky Formation on "Treeless Creek" (Section 82-10). Note the abrupt contact (arrows) between the bioturbated sandstones and the crossbedded sandstones of the member. ISPG photo. 1858-2.

Age

The Red-weathering and Upper members of the Husky Formation contain bivalves of the *Buchia okensis* and *B. uncitoides* zones and possibly the *B. volgensis* Zone. All of these zones are Berriasian (Jeletzky, 1967, 1973). *B. okensis* is present in the North Branch Formation, in close stratigraphic proximity to Barremian strata; consequently, these beds probably represent the oldest part of the Berriasian in the formation. In the northern Ogilvie Mountains, shales immediately overlying the Porcupine River Formation contain fossils of the *B. terebtratuloides* Zone, indicating a latest Tithonian age (Section 85-2; Fig. 2) (Jeletzky, pers. comm., 1985). Based on the paleontological data it would appear that the contact between the Porcupine River Formation/Arenaceous member and the overlying shales is diachronous. Part of the Kingak Formation contains Berriasian bivalves.

Brideaux and Fisher (1976) identified dinoflagellates of the *Paredinia borealis* assemblage in the Husky Formation and immediately overlying strata. Hedinger (1979) proposed a foraminiferal zonation of the Husky Formation and Fensome (1987) recognized zones based on schizaealean spores. In all cases the Berriasian age was based primarily on comparison with macrofossil zones.

Martin Creek Formation

Description

The Martin Creek Formation was named by Dixon and Jeletzky (1991) and replaces the informal term Buff sandstone member (Jeletzky, 1958, 1960, 1961). It is the lowest formation in the Parsons Group (Dixon, 1982). Martin Creek strata are present in the subsurface of the Mackenzie Delta (Dixon, 1982), throughout the northern Richardson Mountains (Jeletzky, op. cit.), the westernmost part of the Keele Range, and in the northern Ogilvie Mountains (Dixon, 1991). West of the Bonnet Lake area the Martin Creek succession commonly cannot be mapped and equivalent strata are included in the Kingak Formation although, in some places, there is a thin succession of interbedded mudstone and sandstone at the equivalent stratigraphic horizon. Pre-McGuire erosion has

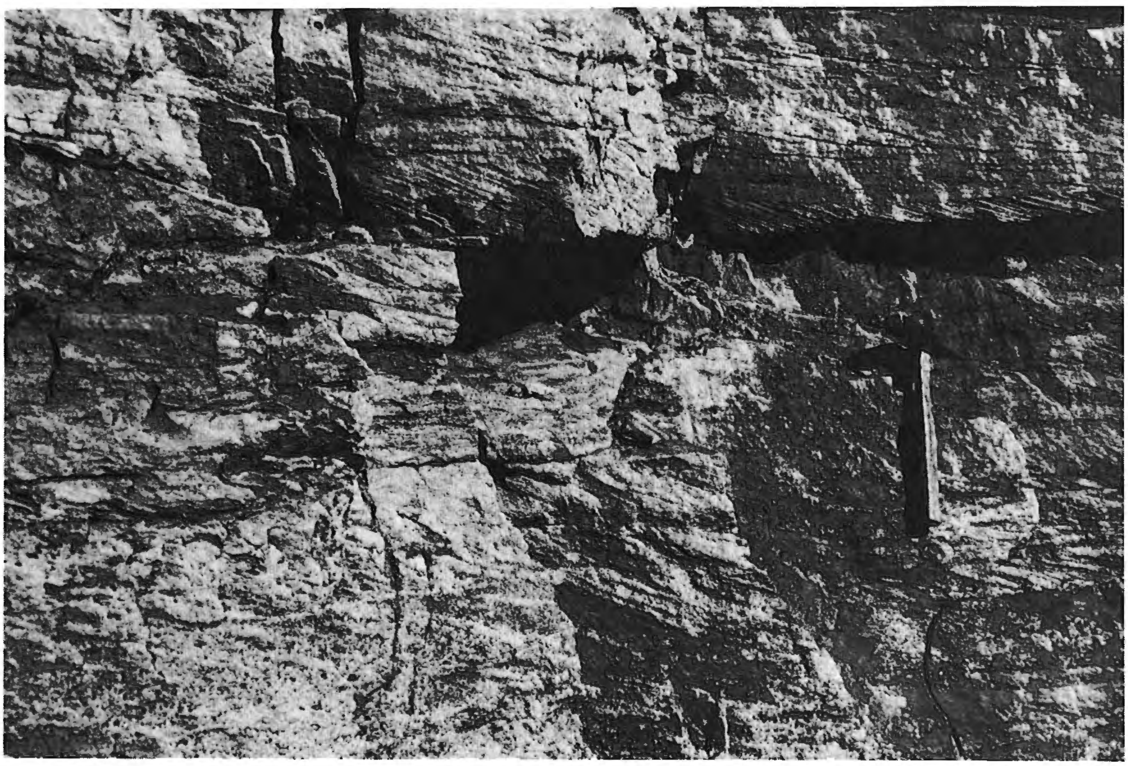

Figure 10. *Small-scale, planar crossbeds in the Arenaceous member of the Husky Formation on "Treeless Creek" (Section 82-10). ISPG photo. 1858-1.*

Figure 11. *Contact between the Husky and Martin Creek formations on Martin Creek (Section 81-2). ISPG photo. 1895-1.*

removed Martin Creek strata south of McDougall Pass in the Richardson Mountains, and on the eastern flanks of Kandik Basin (Jeletzky, 1980; Dixon, 1991) (Figs. 6, 12).

In the Aklavik Range and under parts of the Mackenzie Delta–Tuktoyaktuk Peninsula the Martin Creek Formation is mostly sandstone (Fig. 13), and is about 100 m thick in the northeastern Richardson Mountains and up to 200 m thick under Tuktoyaktuk Peninsula. The succession consists of predominantly fine grained quartz arenites gradationally overlying Husky shale and abruptly overlain by McGuire shale. At Martin Creek the basal beds rest abruptly on Husky strata, although sedimentologically there is no suggestion of a major erosional hiatus (Section 81-2; Fig. 11). Under Tuktoyaktuk Peninsula the transitional contact consists of bioturbated sandy mudstone grading upward into bioturbated argillacous sandstone, and in turn succeeded by stratified sandstone (Fig. 14). The stratified sandstones contain abundant examples of low-angle cross-stratification. In outcrop, hummocky cross-stratification (HCS), swaley bedding, subhorizontal lamination, current and wave-ripple lamination, and long, vertical or U-shaped burrows are common (Fig. 15). Bioturbated beds are commonly interbedded with stratified beds. In the Martin Creek/ "Grizzly Gorge" areas (Sections 81-1 to 3; Fig. 2) the succession has a banded appearance (Fig. 13), the bands varying in thickness from a few metres to several tens of metres. The banding is caused by the alternation of HCS-dominant intervals with intervals in which ripples, bioturbated beds and smaller scale HCS are predominant. The latter type of interval tends to be thinner.

On the western slopes of the northern Richardson Mountains (Figs. 6, 16), and in the northern Ogilvie Mountains, the Martin Creek Formation consists of two or more coarsening-upward intervals. For example, near Mount McGuire (Location 82-8; Fig. 2) and Location 84-27 (Fig. 2) in the Ogilvie Mountains, there are two sandstone intervals separated by a median shale interval up to 60 m thick. The formation in these areas consists of two large-scale, thickening- and coarsening-upward units; the lower one has the upper Husky as its shaly part, and the upper unit with the median shale as its basal beds. The formation is between 120 and 170 m thick. Shale interbeds are very common throughout the coarsening-upward units. Sedimentary structures in the sandstone beds consist of plane lamination, small-scale HCS, wave-ripple lamination, and bioturbation. A few kilometres east of Bonnet Lake, in northern Yukon (Locality 88-15; Fig. 2), the Martin Creek Formation consists of three thick sandstone intervals separated by shales. A fourth, minor sandstone unit is present between the first and second thick sandstone intervals.

On the southwest flank of Barn Mountains, sandy beds are present at a similar stratigraphic level to the Martin Creek Formation but are considerably thinner, more argillaceous, contain more shale interbeds, and generally are thoroughly bioturbated, with only a few scattered remnants of original sedimentary structures (plane- and ripple-lamination). These beds tend to weather in a subdued manner although, locally, small resistant-weathering ridges are present and can be mapped. Around the Canoe Syncline, Martin Creek strata are only locally visible (Section 83-6; Fig. 2) (Norris, 1981c), owing to vegetation cover, and are generally 10 m or less in thickness.

Berriasian strata become progressively shalier to the northwest, such that, on the north flank of Barn Mountains and along the Babbage River, only a few metres of argillaceous siltstone and silty sandstone represent Martin Creek facies (Sections 83-7, 83-10, 87-1, 87-22). These beds cannot be readily differentiated from enclosing strata; hence, they are included in the Kingak Formation.

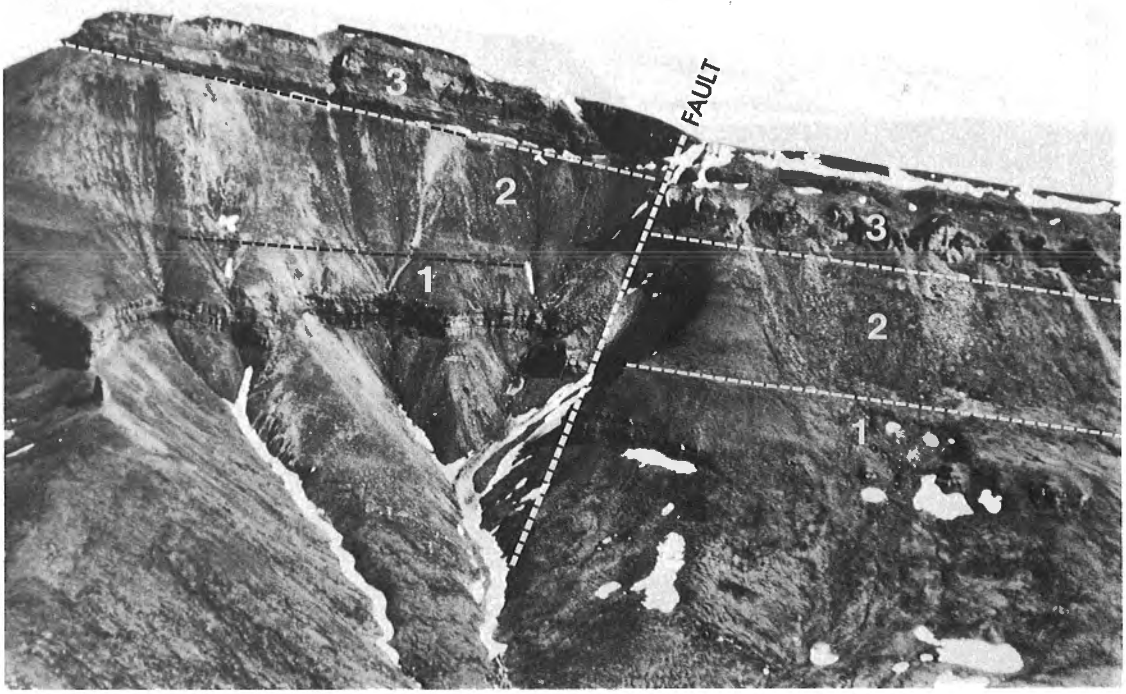

Figure 12. The McGuire Formation, erosionally overlying the upper Husky Formation in the Richardson Mountains (Section 82-5). 1 - upper Husky Formation, 2 - McGuire Formation, 3 - Kamik Formation. ISPG photo. 1858-8.

Depositional environment

From the Mackenzie Delta/Tuktoyaktuk area, westward through the northern Richardson Mountains to the British Mountains, a general shelfward progression of facies can be identified. In the east, Dixon (1982) interpreted the Martin Creek Formation as a vertical change from inner shelf/lower shoreface sands to middle and upper shoreface sands, capped by lagoonal sediment; all formed as part of a prograding barrier island succession. Westward, on the eastern flanks of the northern Richardson Mountains, the Martin Creek Formation is dominanted by storm-produced facies that were deposited in a nearshore to lower shoreface setting. The regular alternation of intervals in which large hummocks are dominant with intervals in which small hummocks, wave ripples and bioturbated beds are more common, can be interpreted as indicating either shifts in the depositional setting—from high on the lower shoreface to low on the lower shoreface or nearshore, respectively—or to alternating periods of greater and lesser storm intensity.

On the western flanks of the northern Richardson Mountains and in the northern Ogilvie Mountains, Martin Creek strata also indicate a depositional environment in which storm deposits were common, but where the normal, low-energy, background deposition of mud was not masked. Also, in these areas there are several coarsening-upward depositional cycles, indicating that there were significant shifts in facies belts during the deposition of Martin Creek strata. These events could be attributed either to a local change in sediment supply or basinwide transgressive events that shifted the facies belts landward. The record for such events in Martin Creek strata east of the Richardson Mountains is absent, or has not been recognized because of the similarity of facies throughout the full succession.

Age

Martin Creek strata contain bivalves of the *Buchia volgensis* and *B. keyserlingi* zones, which indicate a Berriasian to earliest Valanginian age (Jeletzky, 1958, 1960, 1961, 1975b). In places, the base of the formation may extend into the uppermost part of the Berriasian *B. uncitoides* Zone. The base of the formation is a facies boundary and can be anticipated to be diachronous. The top of the formation is a hiatal surface (*sensu* Frazier, 1974) or marine flooding

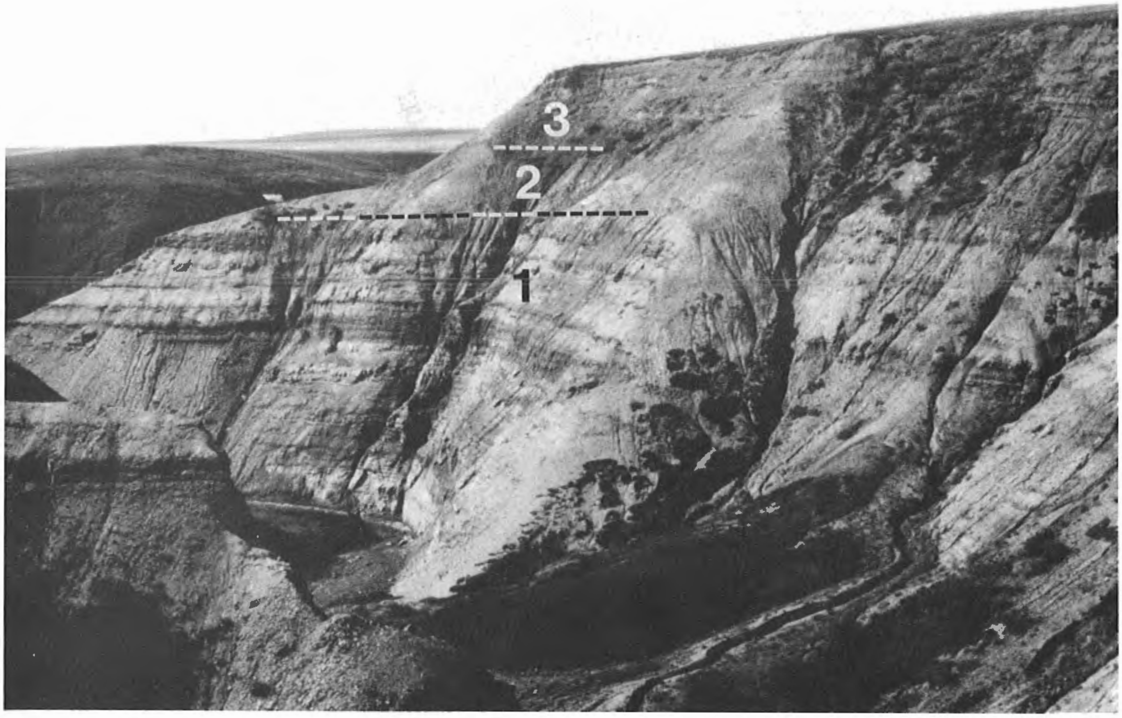

Figure 13. The Martin Creek, McGuire, and Mount Goodenough formations at "Grizzly Gorge" (Section 81-3). 1 - Martin Creek Formation, 2 - McGuire Formation, 3 - Basal sandstones of the Mount Goodenough Formation. ISPG photo. 1673-18.

surface (Van Wagoner et al., 1988) in the basinal areas, and is an erosional unconformity at the basin margins; consequently, it is unlikely to be time-equivalent at all locations. Foraminifers, palynomorphs and dinoflagellates in Martin Creek strata are similar to those found in the upper Husky Formation (Brideaux and Fisher, 1976; Fensome, 1987; S. Fowler, pers. comm., 1986, 1987).

McGuire Formation

Description

The McGuire Formation was named by Dixon and Jeletzky (1991) and replaces the informal term Bluish grey shale division (Jeletzky, 1961). It is the middle formation of the Parsons Group (Dixon, 1982). McGuire strata are widespread throughout northern Yukon and under the Mackenzie Delta/Tuktoyaktuk Peninsula (Dixon, 1986, 1991). Shales of the McGuire Formation rest abruptly on Martin Creek strata throughout much of its occurrence, but, south of McDougall Pass, in the northern Richardson Mountains, and on the east flank of Kandik Basin, the McGuire rests erosionally on Husky and Kingak, or older, strata (Jeletzky, 1980; Dixon, 1991) (Figs. 6, 12). Overlying McGuire shales gradationally are sandstones of the Kamik Formation. Locally, the upper contact may be abrupt, as on the Cache Creek Uplift and under parts of the south Mackenzie Delta and Tuktoyaktuk Peninsula. Where a full McGuire sequence is preserved, the formation ranges in thickness from about 15 m in the Parsons Lake area to about 264 m near Mount McGuire (Section 82-8; Figs. 2, 16). However, there are some very rapid local changes in thickness; for example, a few kilometres south of Mount McGuire the formation thins to 64.5 m. On the north flank of Canoe Syncline it is 143 m thick (Section 83-6; Fig. 2), and in the northern Ogilvie Mountains it is between 40 and 100 m thick. In the northwestern areas, McGuire-equivalent strata are included in the Kingak Formation.

Shale is the dominant lithology in the McGuire Formation. Small ironstone concretions that commonly weather a rust colour are present in the lower part of the formation. Thin (10 cm or less) beds of siltstone and very fine grained, argillaceous sandstone are locally present in the lower part of the formation and increase in frequency and thickness upsection. These thin sandy beds invariably are bioturbated and some contain bivalves, commonly of the genus *Buchia*. In the subsurface, the sandy beds of

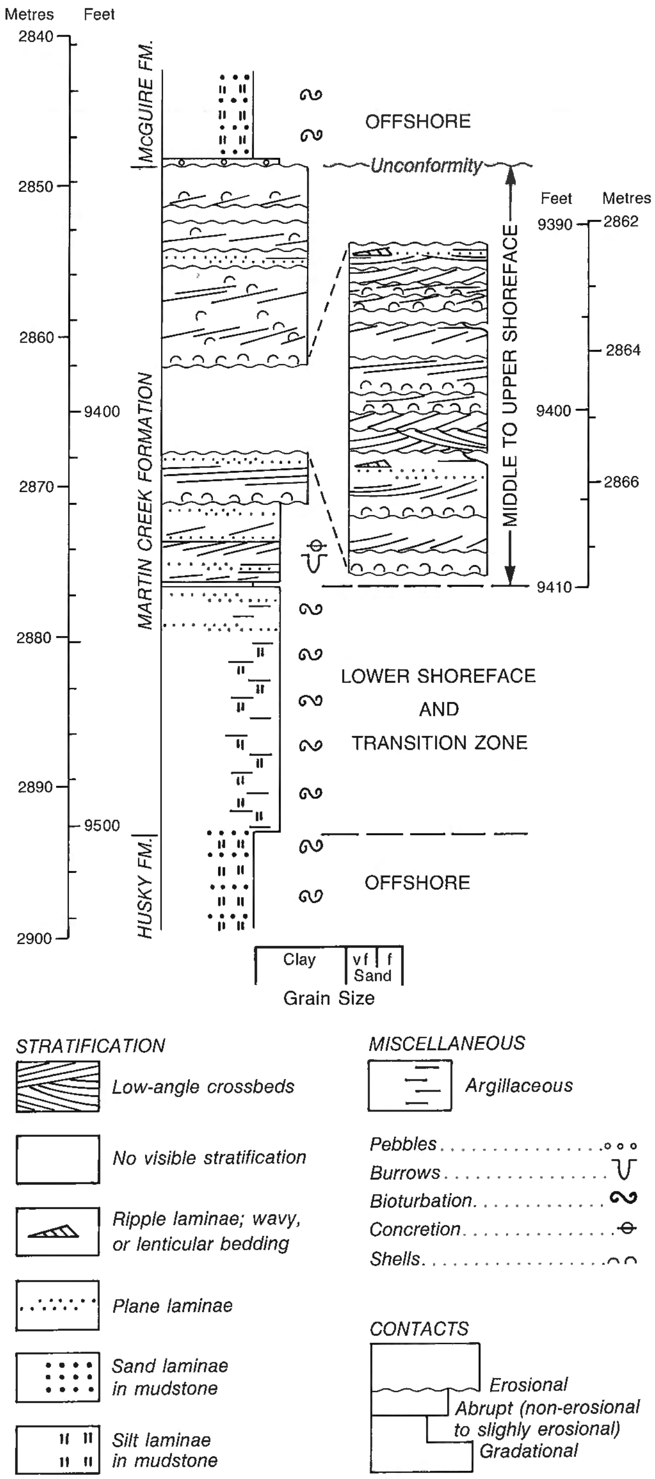

***Figure 14.** A core log of the Martin Creek Formation, from the Parsons F-09 well.*

the formation commonly occur in small-scale, coarsening-upward units (Dixon, 1982, p. 17, 18). In the thicker successions of McGuire strata the uppermost beds contain as much as 50 per cent argillaceous, and generally bioturbated, sandstone. Preservation of primary sedimentary structures in these sandstones is uncommon. On the east flank of Cache Creek Uplift (Sections 81-1, -3, -4, 87-20; Fig. 2) McGuire strata consist of a distinct, thin, friable, black shale that commonly contains numerous belemnites.

Depositional environment

McGuire strata form the lower beds of a large-scale, coarsening- and thickening-upward succession that includes the lower part of the overlying Kamik Formation. As such, these strata represent the initial deposits of progradation, as mid to outer shelf deposits. As progradation proceeded the environment changed from low-energy mud deposition on the mid to outer shelf to slightly higher energy conditions on the mid to inner shelf, where sand was deposited during periods of storm activity but which became completely bioturbated during the calmer periods. In the east, under Tuktoyaktuk Peninsula, sandier interbeds are more common, which is interpreted as reflecting proximity to the presumed shoreline, and the more frequent preservation of storm-introduced coarse clastic rocks on the shelf.

Age

Bivalves recovered from the formation belong to the *Buchia keyserlingi* and *B. inflata* zones (Jeletzky, 1961, 1973) and are dated as early to middle Valanginian. Microfossils have been recovered throughout the formation and, although they constitute a distinct, regionally extensive assemblage (S. Fowler, pers. comm., 1988), insufficient knowledge of the fauna precludes their direct correlation with known Valanginian assemblages. However, for local correlations the microfossil assemblage has proven invaluable, especially where macrofossils have not been found.

McIntyre and Brideaux (1980) identified Valanginian palynomorphs and dinoflagellates in the McGuire Formation at "Grizzly Gorge" (Sections 81-3, -4; Fig. 2) and Martin Creek (Section 81-1; Fig. 2). Although a distinct palynomorph and dinoflagellate assemblage is present in McGuire strata of the northeastern Richardson Mountains, its usefulness for regional correlation is limited to those areas that have not been thermally altered. The least

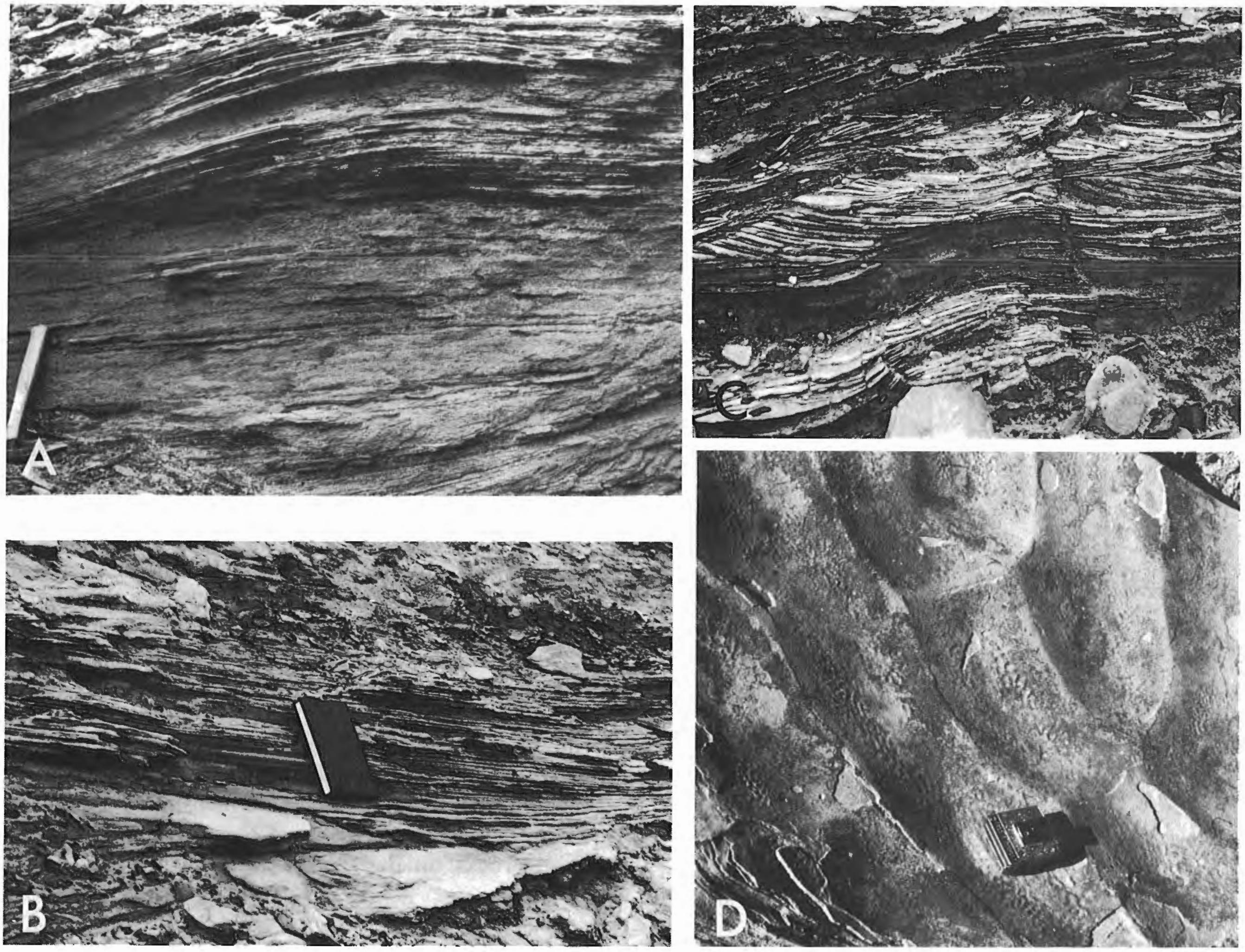

Figure 15. *Stratification types in the Martin Creek Formation.*

A. Hummocky cross-stratification. Hammer is approximately 30 cm long. ISPG photo. 1673-11.
B. Swaley cross-stratification. Notebook is 17 cm long. ISPG photo. 2584-8.
C. Small-scale HCS and ripple crosslamination. ISPG photo. 2584-7.
D. Wave ripples. Tape measure is approximately 6 cm across. ISPG photo. 1673-17.

thermally altered areas are the west flank of the Richardson Mountains and in the subsurface of Mackenzie Delta and Tuktoyaktuk Peninsula.

Kamik Formation

Description

Dixon (1982) introduced the Kamik Formation for a thick, sandstone-dominant succession between the McGuire Formation below and Siku shales above, in the subsurface under Mackenzie Delta/Tuktoyaktuk Peninsula. It is the third and highest formation of the Parsons Group. A similar succession of sandstones occurs throughout much of the northern Richardson Mountains, British Mountains, western Keele Range, and Ogilvie Mountains and it is appropriate to refer to such strata as the Kamik Formation (Fig. 6) (Dixon, 1986b, 1991). Most of these strata have been mapped as unit Kwc by Norris (1981c, d, e, i) and informally identified as the White quartzite division and Coaly quartzite division by Jeletzky (1961, 1971a, 1975b). However, care is needed in some of the outcrop areas,

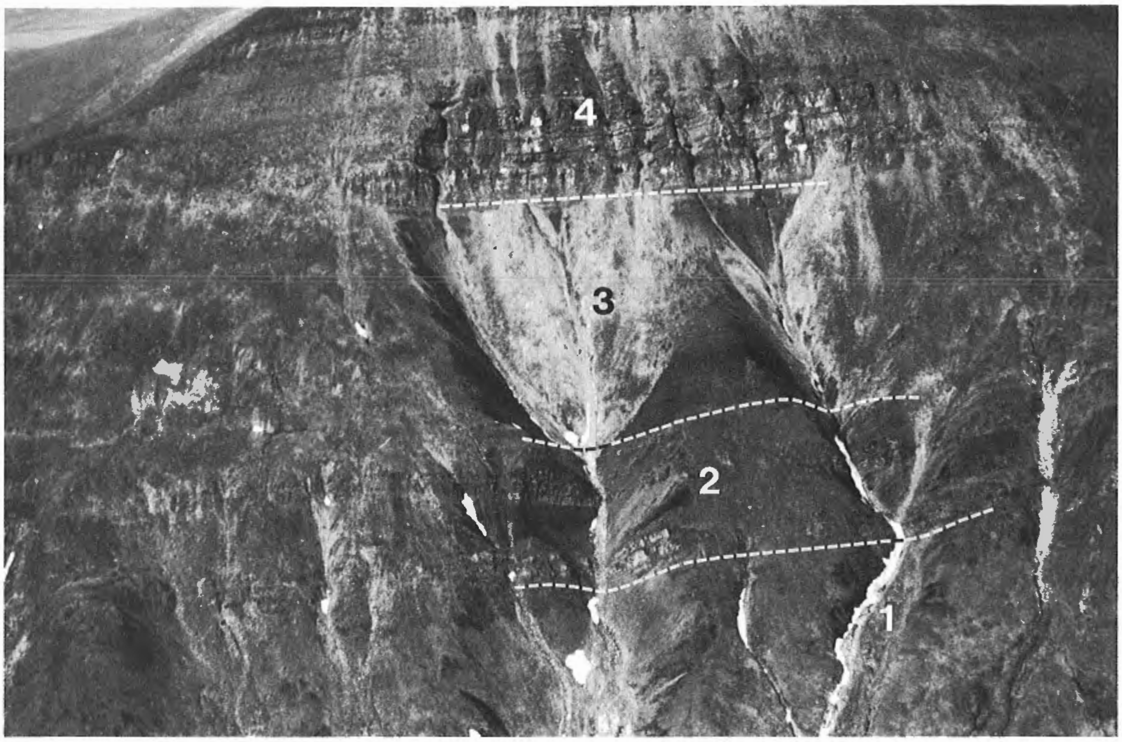

Figure 16. *The Berriasian to Hauterivian succession near Mount McGuire in the Richardson Mountains (Section 82-8). 1 – Husky Formation, 2 – Martin Creek Formation, 3 – McGuire Formation, 4 – Kamik Formation. ISPG photo. 2057-6.*

because there is a sandstone interval locally at the base of the Mount Goodenough Formation that can lie juxtaposed on a truncated Kamik succession and can be easily misidentified as Kamik strata. Such is the case at Martin Creek and "Grizzly Gorge", where Jeletzky's (1975b) informally named White sandstone and Coal-bearing divisions overlie a thin McGuire Formation. In an earlier publication (Dixon, 1982, p. 18), I correlated the White sandstone and Coal-bearing divisions with the Kamik Formation, but the presence of *Simbirskites* in the uppermost sandstones beds of the "Grizzly Gorge" section (Jeletzky, 1975b, fig. 8) and regional mapping of the base-Mount Goodenough unconformity indicate that some of the strata are younger than Kamik. Similarly, in the Babbage River area, a 100 m thick succession of sandstones, mapped as Kwc (Norris, 1981c) and overlying the McGuire, most probably contains some basal sandstones of the Mount Goodenough Formation (Locality 83-5; Fig. 2). This interpretation of the 83-5 locality is based principally on the anomalously thin nature of the sandstone between the McGuire and Mount Goodenough shales. At the nearby Roland Bay L-41 and Spring River N-58 wells there is a sandstone interval, up to 60 m thick, at the base of a dated Barremian shale succession, and overlying Jurassic shales. This stratigraphy is further evidence of a locally thick basal Mount Goodenough sandstone in the Babbage River area. The localities where a basal Mount Goodenough sandstone occurs tend to be on the flanks of tectonic uplifts, where the magnitude of the pre-Mount Goodenough unconformity is greatest and identification of the basal sandstone beds of the Mount Goodenough succession generally is obvious. However, where more complete Cretaceous successions are preserved it is almost impossible to differentiate between the Kamik and basal Mount Goodenough sandstones, unless good biostratigraphic control is available.

In the east, under the Tuktoyaktuk Peninsula/Mackenzie Delta, the Kamik Formation is up to 800 m thick, thinning rapidly toward the Eskimo Lakes Arch. Complete thickness measurements are difficult to obtain in outcrop areas owing to access problems or incomplete sections. However, available field data indicate thicknesses in the order of 500 to 800 m, within the depocentres. Thinning of the Kamik Formation toward tectonic uplifts, such as the Eskimo Lakes Arch, Cache Creek Uplift, and Romanzof

Uplift, is due principally to sub-Mount Goodenough truncation. Where there are closely spaced data points, as in the subsurface of Tuktoyaktuk Peninsula, it can be shown that some of the thinning toward tectonic highs also has a significant depositional component (Dixon, 1982).

Although the Kamik Formation is a sandstone-dominant succession there is a twofold division throughout its area of occurrence, informally designated the Lower and Upper members (Dixon, 1991). The Lower member comprises approximately the lower third of the Kamik Formation, consists of 70 to 80 per cent sandstone and is up to 200 m thick, although 75 to 150 m is more common. In outcrop these beds tend to form cliffs (Fig. 16) and, in the subsurface, they produce typical stacked blocky traces on gamma-ray logs (Fig. 17). In the Aklavik Range of the Richardson Mountains, Jeletzky (1960) identified the White sandstone and Coal-bearing divisions, which correlate with the Lower member of the Kamik Formation (Dixon, 1991). The Upper member comprises the upper two thirds of the formation and contains more interbedded shale than the Lower member. It is up to 500 m thick but is typically in the order of 200 to 300 m. The succession is commonly arranged into a series of coarsening- and thickening-upward cycles (Figs. 17, 18). In northwestern Yukon (British Mountains and northern Ogilvie Mountains), the lowest beds of the Upper member are thick shales, which can be mapped as a distinct local unit (e.g., map unit Kwc2 in the Canoe Syncline, Norris, 1981c) (Section 83-6; Fig. 2). In general, the amount and thickness of shale interbeds increases toward the west and northwest.

Under Mackenzie Delta the Lower member is characterized by fining-upward cycles in the lower part, overlain by interbedded sandstone and shale in the upper part (Dixon, 1982). The fining-upward cycles typically have a basal scoured surface overlain by massive or crossbedded, pebbly, medium to coarse grained sandstone. This sandstone grades upward into finer grained sandstone, commonly interbedded with thin mudstone beds. Thin coal seams or carbonaceous mudstone beds may be present in the upper part of some fining-upward cycles. In the upper part of the Lower member the thin bedded sandstones tend to be bioturbated. The vertical character change in the Lower member seen in the subsurface is also seen in the Aklavik Range, although the facies differ. In parts of the Aklavik Range the lowermost beds are fine grained and contain long, low-angle cross-stratification (Fig. 19B). In other areas, the lowermost beds are trough cross-stratified, medium to coarse grained

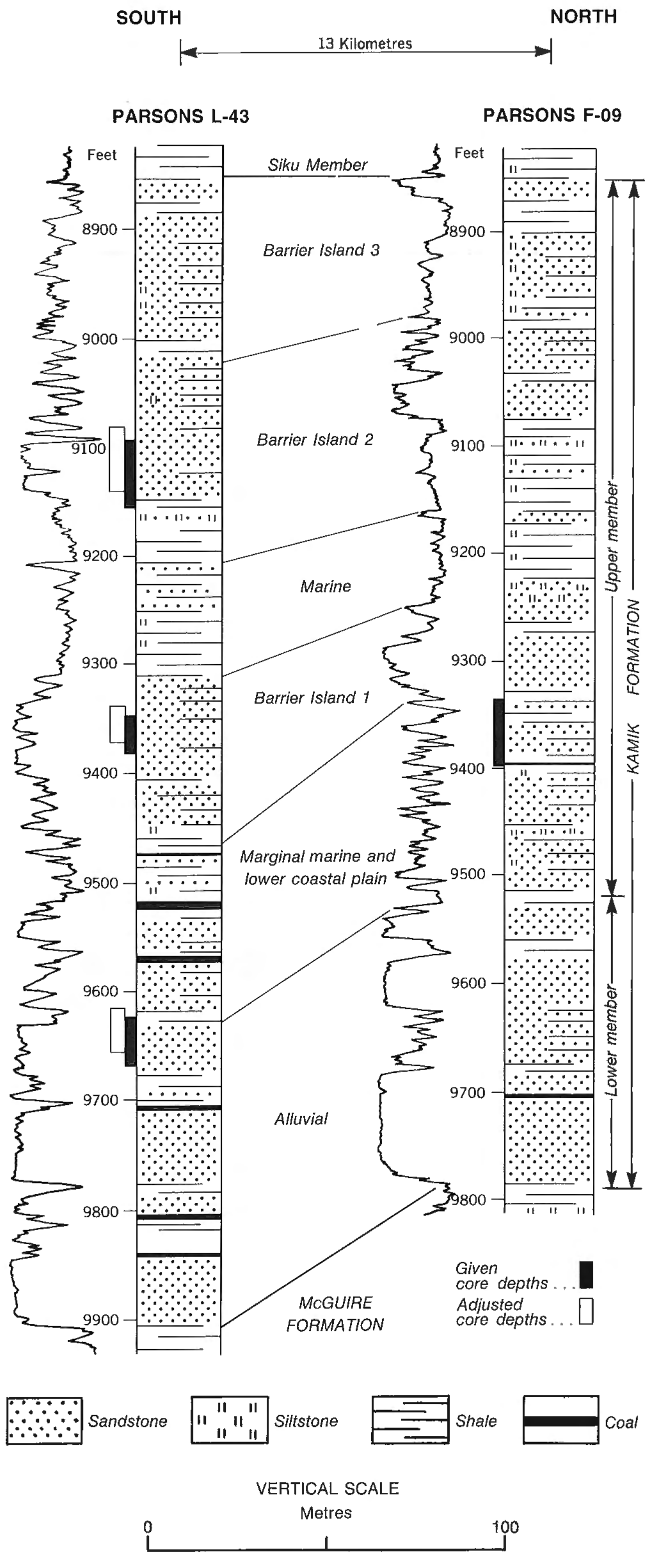

Figure 17. Gamma-ray signature of the Kamik Formation in the Parsons L-43 and F-09 wells. Interpreted depositional environments are shown.

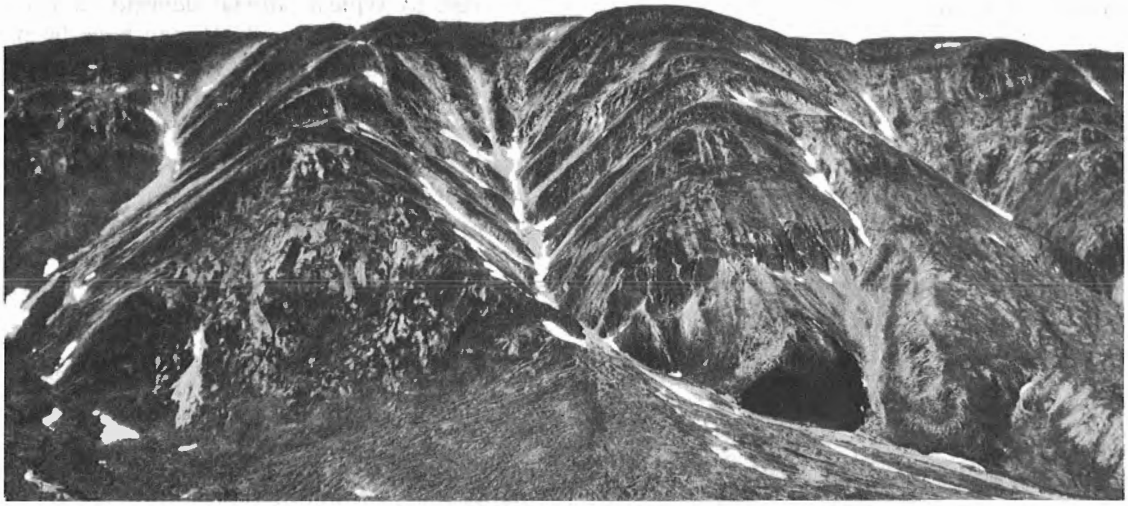

Figure 18. The Upper member of the Kamik Formation at Section 83-2B, east of Bonnet Lake. The ribbed appearance is due to the presence of interbedded shale and sandstone in coarsening-upward cycles. The black shale in the middle foreground is the Mount Goodenough Formation. ISPG photo. 2057-9.

sandstone. The upper beds of the Lower member are thinner bedded units of sandstone, shale and, locally, coal (Jeletzky's Coal-bearing division, 1960) (Fig. 20). These upper beds contain abundant wave and ripple lamination (Fig. 19C) and trough crossbeds (Fig. 19A), and include burrowed beds. Grain size in the upper beds ranges from very fine to coarse, with local occurrences of granular and pebbly sandstone.

Westward, in the Richardson Mountains, Barn Mountains, Keele Range, and northern Ogilvie Mountains, the Lower member of the Kamik Formation consists of bioturbated lowermost beds overlain by plane laminated and hummocky cross-stratified beds (Fig. 19D). Vertical escape burrows are preserved locally in the stratified beds. Also present in parts of the Richardson Mountains, but not very common, are thin beds (10 to 20 cm) of planar crossbedded sandstone, usually arranged in cosets. Grain size is very fine to fine, with local intervals of medium to coarse grained sandstone generally present in the planar crossbedded intervals. Burrowed and burrow mottled beds are more common in the westernmost occurrences of the member.

The Upper member of the Kamik Formation also shows distinct east to west changes. Under the Tuktoyaktuk Peninsula/Mackenzie Delta, this part of the formation consists of several coarsening- and thickening-upward cycles (Dixon, 1982). Similar cycles are present throughout the area of occurrence of the Upper member (Fig. 18). In the east, these cycles grade upward from shale into interbedded shale and sandstone, in turn overlain by a sandstone-dominant sequence that is commonly capped by another sandstone-shale sequence in which thin coal seams may be present. Sedimentary structures include bioturbated or ripple laminated sandstone in the lower beds, with low-angle planar crossbeds common in the sandstone-dominant sequence. Channel-like features are common in the sandstone-dominant sequences. The upper sandstone-mudstone sequence is characterized by ripple lamination, plane lamination, planar crossbeds, and bioturbated beds. In the Richardson Mountains and westward the coarsening-upward cycles are dominated by ripple lamination, plane lamination, hummocky cross-stratification, and bioturbated beds in the sandstone facies. Marine bivalves have been found in some sandstones but are generally very scarce. Grain size in most of these cycles rarely exceeds fine grade in the western occurrences, but medium grained sandstone and shale clasts are present in the Upper member in the eastern areas. In the vicinity of Kandik River (Section 86-21; Fig. 2) the Upper member is again dominated by shale-sandstone cycles, but there are thin coal seams and carbonaceous shales within some of the lower shale units. The sandstone units consist of thin interbeds of wave- and current-ripple laminated and bioturbated sands. In the northwestern areas, on the southern flanks of Barn and British mountains, the Upper member contains a considerable amount of shale, although intercalated sandstone is still a significant component.

Depositional environment

The lowermost beds of the Lower member generally are in gradational contact with the underlying McGuire shale and represent the westward to northwestward progradation of a shoreline. Under Mackenzie Delta and Tuktoyaktuk Peninsula, the Lower member consists of thin shoreface or delta-front deposits overlain by typical alluvial deposits in fining-upward cycles (Dixon, 1982), which may have been deposited on a delta plain. In the Aklavik Range the very long, very low-angle crossbeds in the lowest part of the Lower member appear to be typical beach lamination. Farther west, the lower beds are more typical of lower shoreface to shallow shelf deposits, characterized by bioturbated strata and beds formed by storm-related

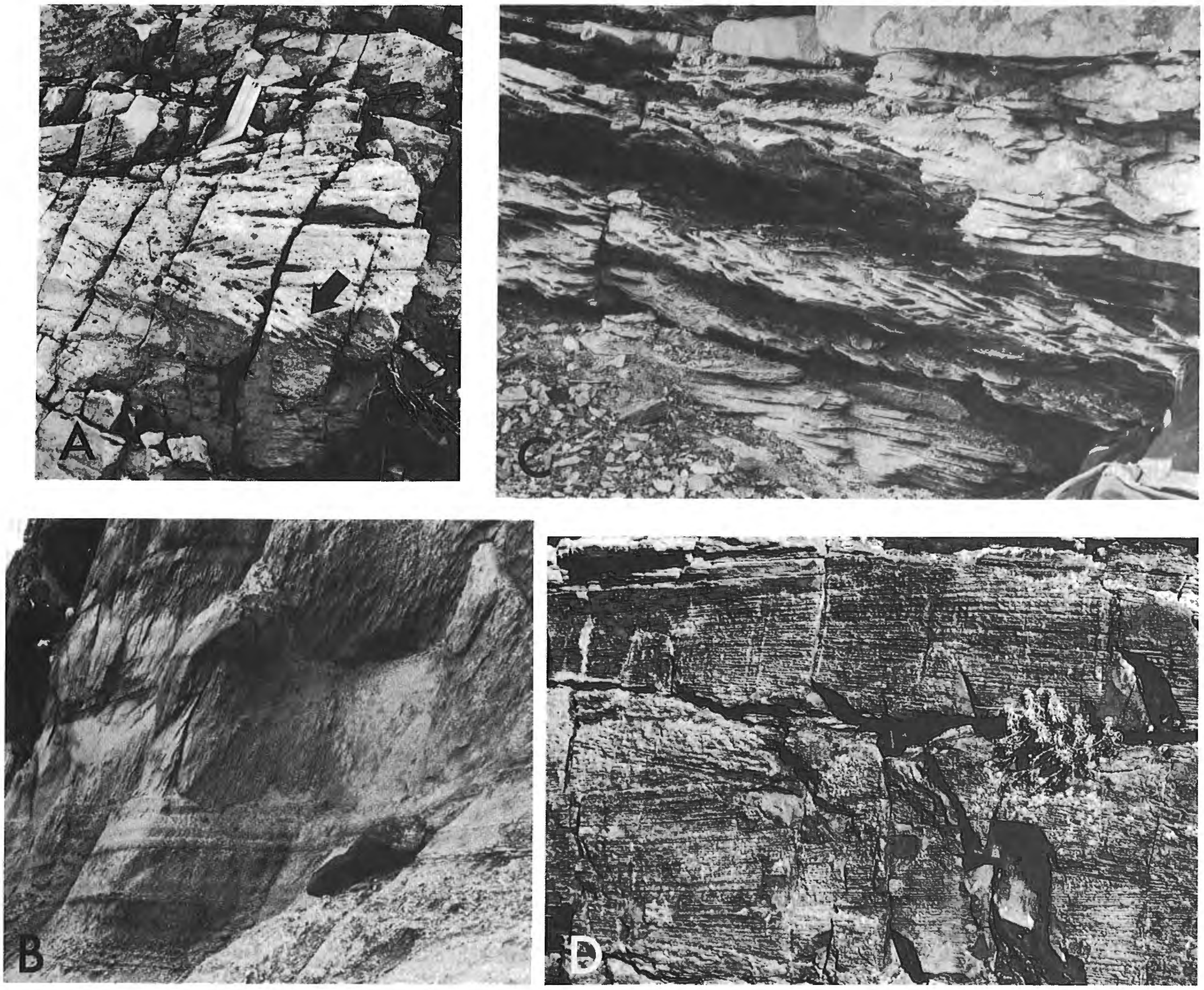

Figure 19. *Stratification types in the Lower member of the Kamik Formation.*

A. Large-scale trough crossbedding. Note the opposing dips (arrow), giving a false impression of planar crossbedding. Lower Canyon, Willow River. ISPG photo. 1858-11.
B. Very long, very low-angle cross-stratification. Martin Creek. ISPG photo. 1895-5.
C. Wave-modified current ripples. Lower Canyon, Willow River. ISPG photo. 1858-16.
D. Hummocky cross-stratification. Near Babbage River. ISPG photo. 2057-2.

processes. Overlying the lowest strata of the Lower member in the eastern areas are beds that were deposited under the influence of both unidirectional and oscillatory flow. The association of such current-generated structures with bioturbation, and the presence of thin coal seams, suggests a coastal plain setting, with deposits of lagoonal, shoreface and possible tidal flat origin (Dixon, 1982). The vertical change from delta plain to coastal sedimentation could be interpreted as reflecting a change from overall progradation to transgression, during a period of high sedimentation rates. Conversely, a decline in sedimentation rates could have induced transgression and abandonment of deltaic sedimentation. Superimposed on the changes in sedimentation was a continuously subsiding basin. However, subsidence was not uniform, as is evident from the growth of local structures, such as the faulted anticline of Parson Lake (Coté et al., 1975).

The Upper member of the Kamik Formation is characterized by a series of small-scale transgressive–regressive events that resulted in the production of the coarsening-upward cycles. In the Tuktoyaktuk Peninsula/Mackenzie Delta area these cycles have been interpreted as prograding barrier island deposits (Dixon, 1982), with a basal transgressive sandstone overlain by offshore sands and muds, in turn overlain by shoreface and tidal inlet deposits. Capping these cycles are lagoonal deposits, some of which contain thin coal beds. To the west, these cycles are entirely marine and represent the shelf equivalents of the barrier island deposits. The western cycles are dominated by storm produced sedimentary structures, but, in the westernmost areas, bioturbated beds are more common. In the Kandik area the cycles in the lower beds of the Upper member appear to be lagoonal in origin, as is evident from the association of wave- and current-rippled sandstone, bioturbated beds with thin coal seams, and carbonaceous shale.

Jeletzky (1961, 1972, 1975b) indicated that his White quartzite and Coaly quartzite divisions (equivalent to the Kamik Formation) contain some nonmarine strata in some areas that I interpret as entirely marine. His conclusions appear to be based on the presence of carbonaceous debris and coaly beds, some medium to coarse grained, crossbedded

Figure 20. *Jeletzky's (1958, 1960) "Coal-bearing division" in the lower canyon of Willow River (looking across the river from Section 82-4). This division is equivalent to part of the Lower member of the Kamik Formation. ISPG photo. 1895-3.*

sandstones, and a lack of marine fossils. In the areas I have visited, many of which are exactly the same as those examined by Jeletzky, coal or coaly beds have only been found in the Kandik and Willow River areas, although carbonaceous debris is locally common on bedding planes. Although it is possible that medium to coarse grained sandstone beds are present in the western areas, they are uncommon. The criteria used by Jeletzky to conclude that nonmarine strata are present in some areas are inadequate, or an overemphasis of a minor character. The suites of sedimentary structures that I have observed are more typical of marine realms and the coal or coaly beds appear to be lagoonal deposits.

Age

The age of the Kamik Formation is poorly constrained by the sparse, indigenous fossils. Macrofossils present in the formation tend to be non-age-diagnostic bivalves. However, Jeletzky (1973, p. 67) reported that bivalves of the *Buchia* ex gr. *inflata-sublaevis* Zone (Valanginian) are present in beds equivalent to the lowermost Kamik Formation. This was confirmed by a collection of bivalves from the lowermost beds of the Lower member of the Kamik Formation at "Grizzly Gorge", which were identified as *Buchia* n. sp. aff. *inflata* (Jeletzky, pers. comm., 1988). Elsewhere on the eastern slopes of Richardson Mountains, the bivalves *Buchia crassa* and *B.* n. sp. aff. *crassa* have been identified in the lowermost Kamik strata (Jeletzky, 1960). The fauna indicates a mid or late Valanginian age.

Recovery of foraminifers and palynomorphs from the Kamik usually is poor and those present can only be used to support a general Neocomian age. However, in the Babbage River area (Section 87-1; Fig. 2) a much shalier succession of Kamik-equivalent strata has yielded a good foraminiferal assemblage. The assemblage has some similarities to those found in the Mount Goodenough and McGuire formations, but with sufficient different species to make it distinct (S. Fowler, pers. comm., 1988).

The youngest age of the Kamik Formation is bracketed by the overlying formation, which is the late Hauterivian to Barremian Mount Goodenough Formation. From the data available it can be concluded that the maximum age range of the Kamik Formation is from mid Valanginian to late Hauterivian, but the range could be from the late Valanginian to middle Hauterivian.

Mount Goodenough Formation

Description

The Mount Goodenough Formation was named by Dixon and Jeletzky (1991) and replaces the informal names Upper shale-siltstone and Dark-grey siltstone divisions (Jeletzky, 1958, 1961). It overlies a variety of units conformably to unconformably, and is overlain either by the sandstone-dominant Rat River Formation (Fig. 6), or shale-dominant Albian units. It is a shale- and siltstone-dominant unit that is widespread throughout the northern Yukon and northern Richardson Mountains (map units KMG and, in places, KBI, although the latter is an incorrect designation; Norris, 1982a). The original description of the Upper shale-siltstone division was from the eastern slopes of Mount Goodenough in the Aklavik Range, Richardson Mountains (Jeletzky, 1958), which is the type area for the formation. At the type area the strata rest unconformably upon older strata, originally identified as Lower sandstone division (Jeletzky, 1958) but subsequently identified as upper Husky formation (Dixon and Jeletzky, 1991), and are overlain by the Rat River Formation (Upper sandstone division of Jeletzky, 1958). Jeletzky (1958) recognized two members in the Upper shale-siltstone division, a lower shale-dominant member and an upper member of interbedded shale, sandy siltstone and silty sandstone. He considered the contact with the overlying Rat River Formation to be gradational. The contact with Rat River strata is readily placed at the base of a cliff-forming sandstone (Fig. 21), which, on close inspection, is an abrupt and erosional contact (Fig. 22). However, on the west flank of the Richardson Mountains, the contact between the Mount Goodenough and Rat River formations is gradational (Fig. 23).

In the subsurface of Mackenzie Delta, Dixon (1982) recognized the Siku shale between the Kamik and Mount Goodenough formations. Later, Dixon et al. (1989) relegated the Siku to member status in the Mount Goodenough Formation. This change was based on the fact that the base-Mount Goodenough unconformity was originally placed too high in the succession.

Jeletzky (1960, 1974, p. 17, 18) noted the presence of a locally developed sandstone facies at the base of the Mount Goodenough Formation, and reported that this facies is up to 300 m thick between Barrier and Vittrekwa rivers, on the east flank of the northern Richardson Mountains. These basal sandy beds appear to be present on and adjacent to tectonic uplifts and

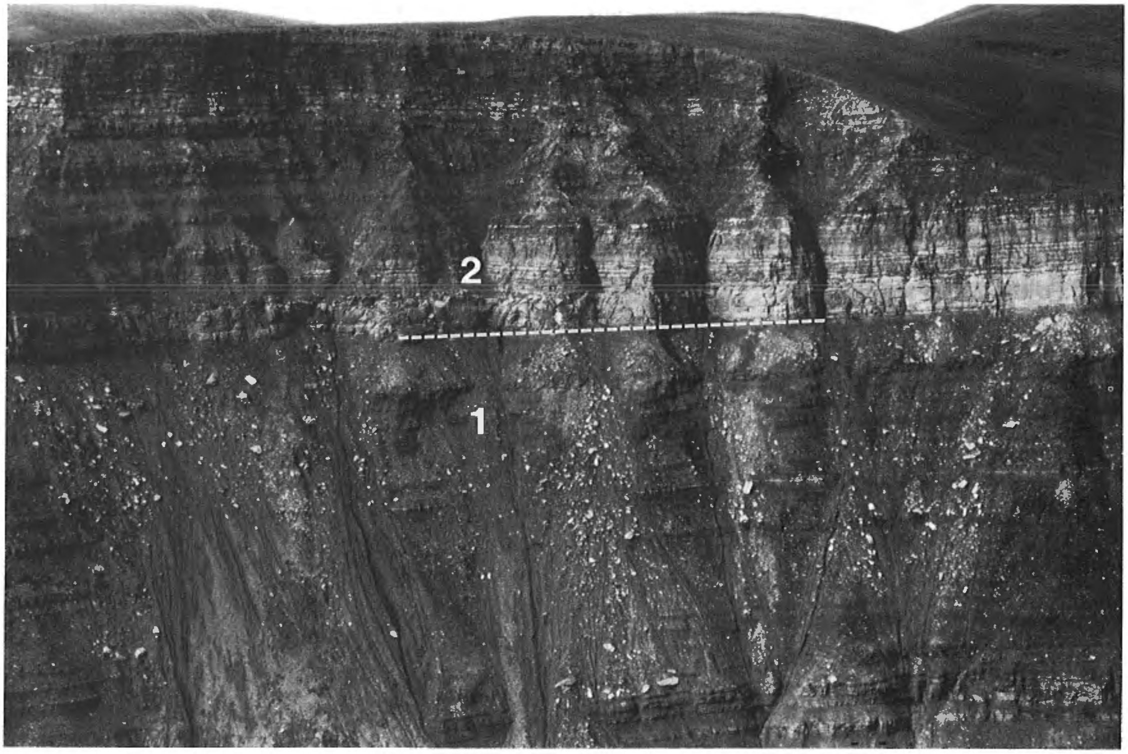

Figure 21. Abrupt contact between the Mount Goodenough (1) and Rat River (2) formations at Mount Goodenough in the Richardson Mountains. ISPG photo. 2236-11.

their thickness can vary quite dramatically over a short distance. For example, in the Martin Creek/"Grizzly Gorge" area, on the east flank of the northern Richardson Mountains, there are 5 to 20 m of basal Mount Goodenough coarse clastic rocks, whereas, 28 km to the south-southeast, at Mount Goodenough, there is only a locally present thin conglomerate a few centimetres thick.

At the type area, Jeletzky (1958) measured between 450 and 527 m of Mount Goodenough strata; of which 300 to 360 m are in the Lower member and 150 to 167 m are in the Upper member. Dixon (*in* Dixon and Jeletzky, 1991) measured only about 300 m at the type section. Elsewhere, Jeletzky (1960, 1974) noted thicknesses in excess of 900 m in other parts of the Richardson Mountains. In the Kugmallit Trough the formation is possibly up to 1000 m thick. Approximately 200 m of strata are present in the Kandik River area. Elsewhere in northern Yukon thickness measurements are not available, due principally to poor exposure of this unit.

Where present, the basal sandy beds consist of interbedded sandstone, siltstone, shale and, locally, conglomerate. Sandstones range in grain size from very fine to coarse, although very fine to fine grades are most common. Assemblages of sedimentary structures are varied and include planar crossbeds, plane lamination, wave- and current-ripple lamination, bioturbated beds, small-scale trough crossbeds, and hummocky cross-stratification.

The best known areas in which the basal sandstones have been documented are in the vicinity of Martin Creek, "Grizzly Gorge", and the North Branch of Vittrekwa River (Sections 81-1 to -4, 82-13, 87-20, 89-3; Fig. 2), all on the eastern flank of the northern Richardson Mountains (Fig. 24). The uppermost 5 to 20 m of the sandstone beds at "Grizzly Gorge" are considered to be basal Mount Goodenough strata, based, in part, on their faunal content (Jeletzky, 1975b, fig. 8, Section G4) and also on stratigraphic and mapped relationships with adjacent strata. At "Grizzly Gorge", Jeletzky's (1960) White sandstone member (lower Kamik Formation) is progressively truncated to the west by the Mount Goodenough Formation (Fig. 25). The basal Mount Goodenough beds consist of interbedded sandstone, shale and, locally, conglomerate, commonly overlain by a very distinctive rusty weathering sandstone, in turn abruptly overlain by a thick succession of shale. The rusty weathering sandstone is at least 8 m thick, medium to coarse grained and replete with long, vertical and U-shaped burrows. Traces of planar and trough crossbedding can be discerned in places.

Along the banks of the North Branch of Vittrekwa River (Section 82-13; Fig. 2) the basal sandstones of the Mount Goodenough Formation erosionally overlie the Jurassic–Cretaceous North Branch Formation. There, the strata consist of fine to coarse grained sandstone, in which glauconite is abundant. Horizontal and ripple lamination and bioturbated beds are common in the thin beds of the interval, and planar crossbeds are present in the thicker sandstone beds. The basal sandstones are estimated to be 30 to 40 m thick and are overlain abruptly by shale and siltstone.

The basal beds at "Grizzly Gorge" and North Branch differ from the basal beds at Philip Creek (Section 83-5), Trail River (Section 83-9), and near Crow River (Section 87-4). At the last two localities the sandstones are very fine to fine grained and consist of interbedded, bioturbated, subhorizontally laminated, and hummocky cross-stratified units.

The most southerly known occurrence of the basal sandstone of the Mount Goodenough Formation is on the north bank of Peel River (Locality 86-10; Fig. 26), a few kilometres downstream from the confluence of Hart and Ogilvie rivers. There, the sandstone erosionally overlies Permian strata, although there is very little obvious angular discordance. There are approximately 10 m of very fine to fine grained sandstone. Access to the lower few metres of this unit was impossible due to high water-level. The sandstone in the upper few metres contains burrows and burrow mottling and is argillaceous. The sandstone is abruptly overlain by shale, the first few metres of which contain scattered, highly polished granules and small pebbles of black chert.

Throughout the study area a rather monotonous succession of dark grey shale, interbedded with thin siltstone and silty sandstone beds, overlies the basal sandstone. The number and thickness of siltstone and sandstone beds increases upsection. These units are invariably bioturbated, although traces of plane and ripple lamination may be present. In many places there are no sandy basal beds and the shales rest directly on

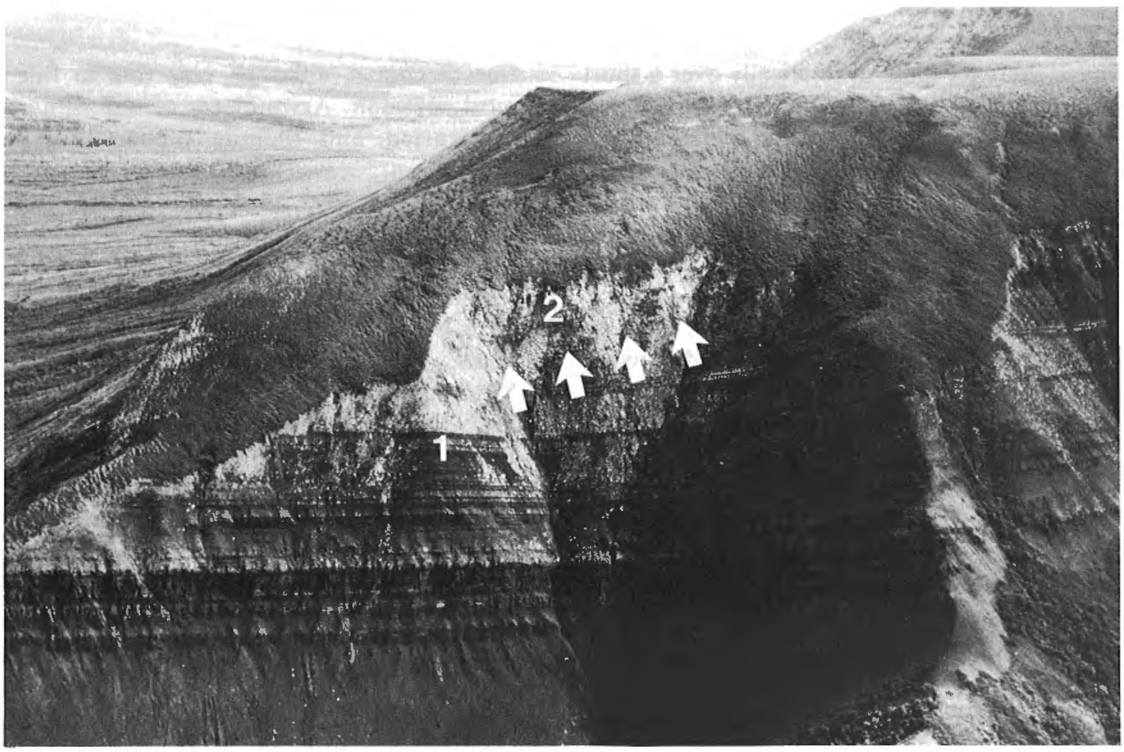

Figure 22. *Erosional contact (arrows) between the Mount Goodenough (1) and Rat River (2) formations at Jimmy Creek, a few kilometres north of Mount Goodenough. Photographed perpendicular to the view in Figure 21. ISPG photo. 2236-9.*

Figure 23. *Transitional contact between the Mount Goodenough (1) and Rat River (2) formations at Fish River (Section 84-8). ISPG photo. 2236-2.*

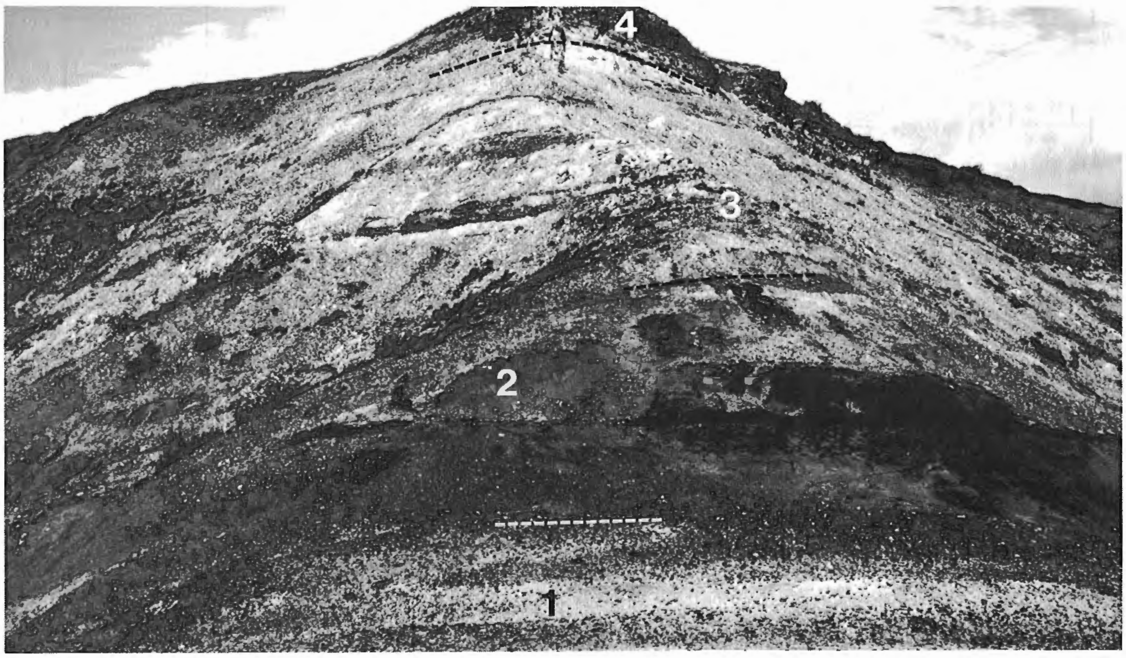

Figure 24. *Basal sandstones of the Mount Goodenough Formation, overlying the Kamik, McGuire, and Martin Creek formations at "Grizzly Gorge" (Section 81-3). 1 - Martin Creek Formation, 2 - McGuire Formation, 3 - Kamik Formation, 4 - Mount Goodenough Formation. ISPG photo. 1673-21.*

older strata; for example, at Fish River (Section 84-7; Fig. 27) where the shale rests on Berriasian strata. Rust-coloured ironstone concretions are common in the lower, shalier part of the Mount Goodenough Formation. Along Fish River, strata of the Mount Goodenough Formation contain a large-scale, synsedimentary slide (Fig. 28).

Depositional environment

The basal sandy beds of the Mount Goodenough Formation contain suites of sedimentary structures that are marine in character. Also present are marine bivalves, ammonites and foraminifers. The basal sandy beds in the "Grizzly Gorge" area can be correlated

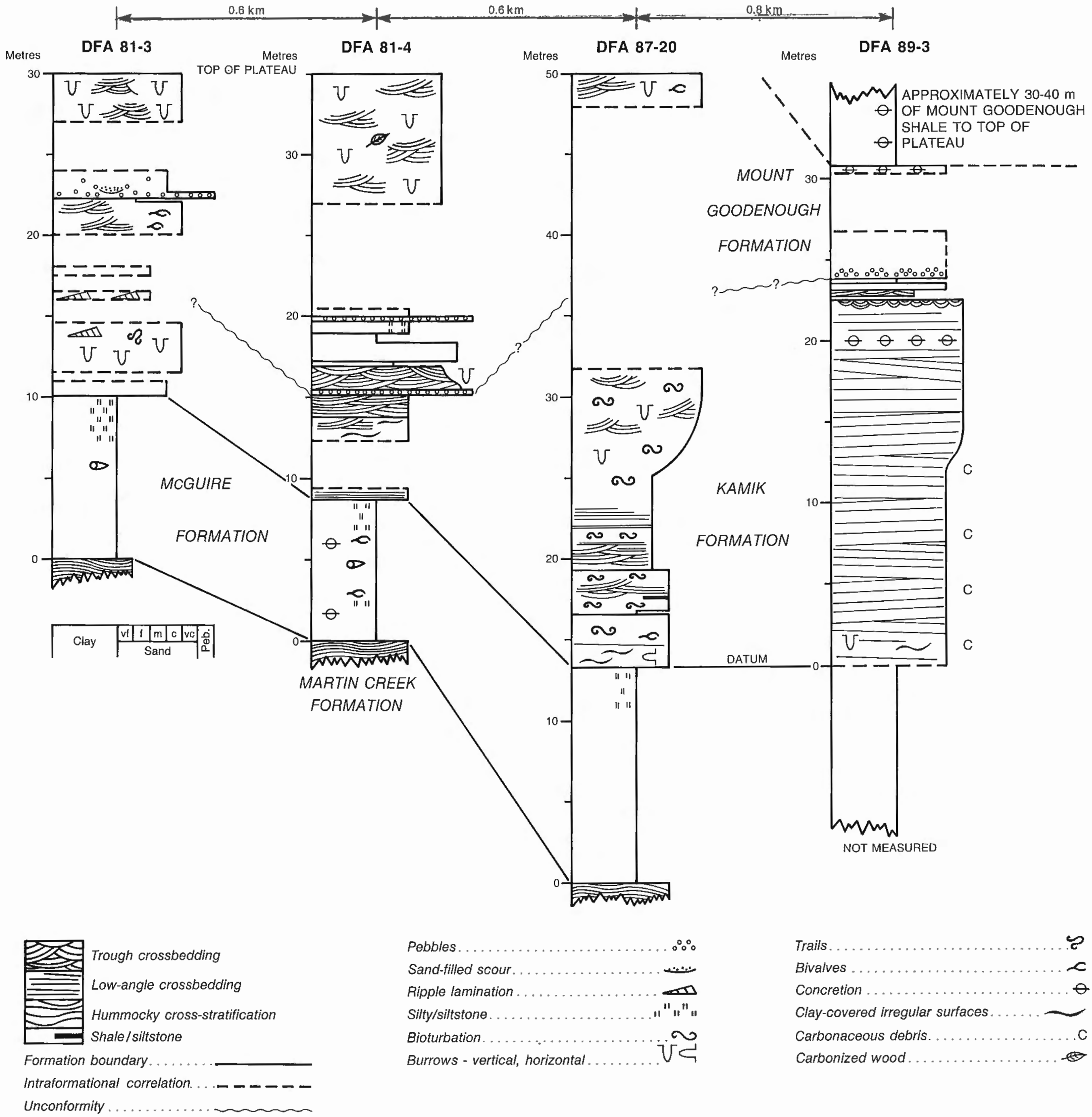

Figure 25. Lithological logs of closely spaced sections in "Grizzly Gorge", illustrating the progressive westward truncation of the Lower member of the Kamik Formation.

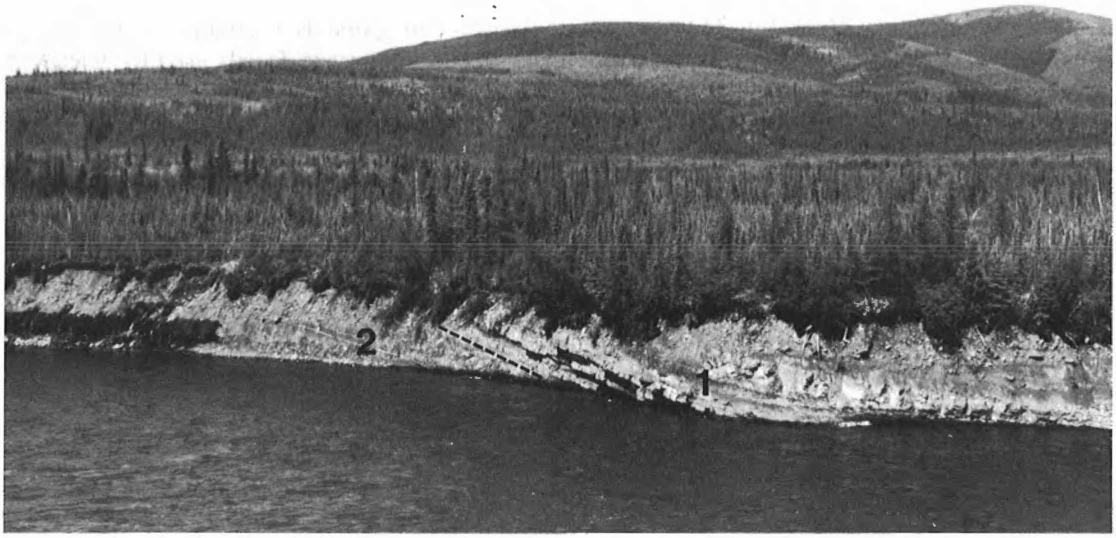

Figure 26. *Basal sandstone of the Mount Goodenough Formation (1), unconformably overlying Permian strata (2) at Section 86-10 on Peel River. ISPG photo. 2619-17.*

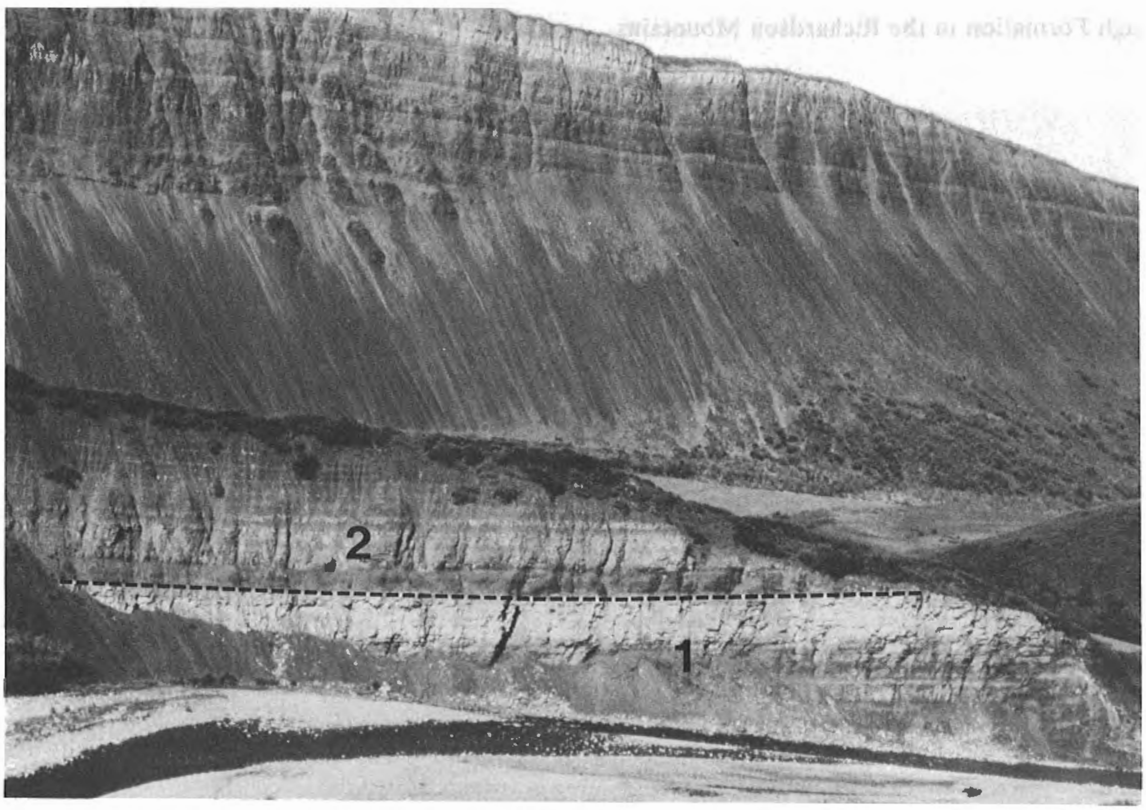

Figure 27. *Mount Goodenough Formation (2), unconformably overlying Martin Creek strata (1) at Fish River (Section 84-7). The light grey strata at the base of the Mount Goodenough Formation are silty shales. ISPG photo. 2236-8.*

into the subsurface to the east and their area of occurrence forms a linear belt about 30 km wide oriented to the north-northwest (Fig. 29). This feature can be interpreted as an infill of an erosional surface with considerable local topographic relief, and some of the low areas possibly were sites of estuaries that were infilled during transgression.

Most of the Mount Goodenough Formation was deposited during progradation, and the bulk are low-energy, fine grained deposits, containing marine bivalves, belemnites, ammonites, and foraminifers. Much of the lower part of the formation was probably deposited on mid to outer shelf, and possibly slope, areas. The large synsedimentary slide at Fish River is evidence of an unstable setting, such as the outer shelf or upper slope. As progradation proceeded, and sediment aggraded, more sand and silt were deposited, and the depositional environment became more mid to inner shelf in character in the upper part of the formation.

Age

Macro- and microfossils are common in the Mount Goodenough Formation in the Richardson Mountains, but are less common in the western areas. Jeletzky (1958, 1960) dated the formation as late Hauterivian to Barremian, possibly extending locally into the Aptian. The principal macrofossils used by Jeletzky are species of the ammonites *Simbirskites, Oxyteuthis,* and *Crioceratites*. The basal sandy beds contain a distinct macrofossil assemblage in which species of the ammonite *Simbirskites* are considered to indicate a late Hauterivian age. Barremian fossils first occur very close to the top of the basal sandy beds. Wherever preservational conditions were favourable, foraminifers and palynomorphs are present and many of the species are specific to the Mount Goodenough succession (Fowler, 1985; D. McIntyre, pers. comm., 1986). The ages indicated by the microfossils are in agreement with those of the macrofossils.

Rat River Formation

Description

The Rat River Formation was named by Dixon and Jeletzky (1991) and replaces the informal name Upper sandstone division (Jeletzky, 1958). The type section is located on the lower reaches of Rat River. It was first described from the Mount Goodenough area however,

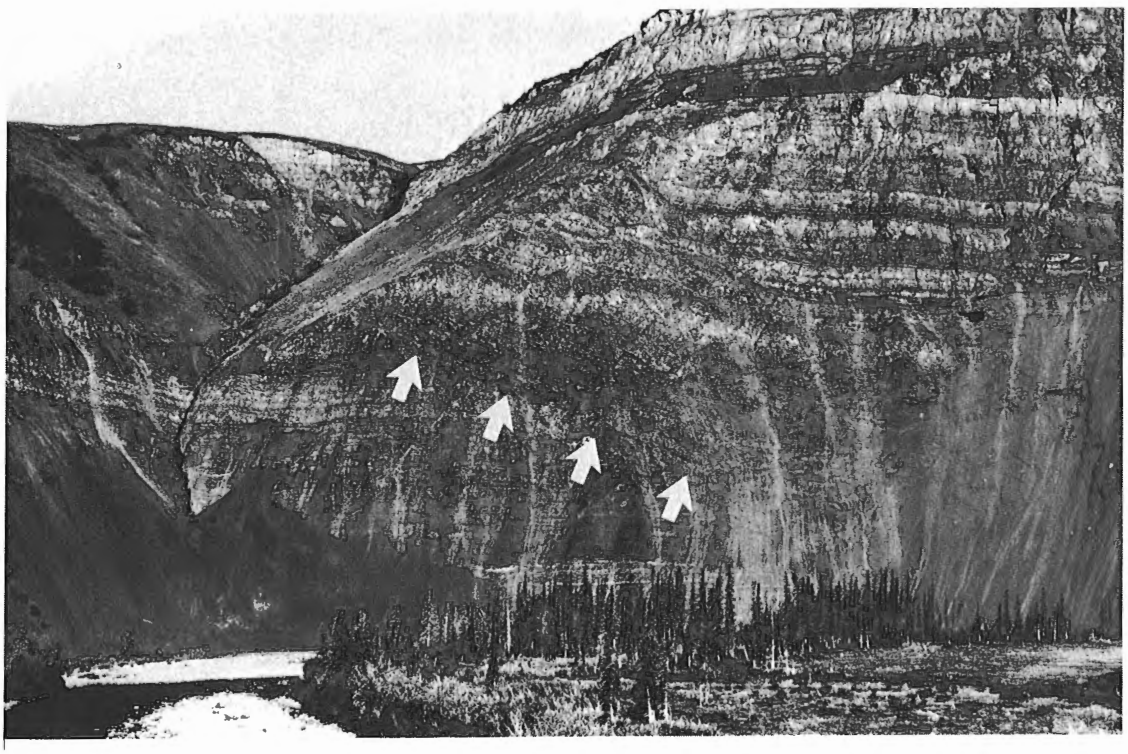

Figure 28. *Large, internal slide (arrows) within Mount Goodenough strata at Section 87-18 on Fish River. ISPG photo. 2846-11.*

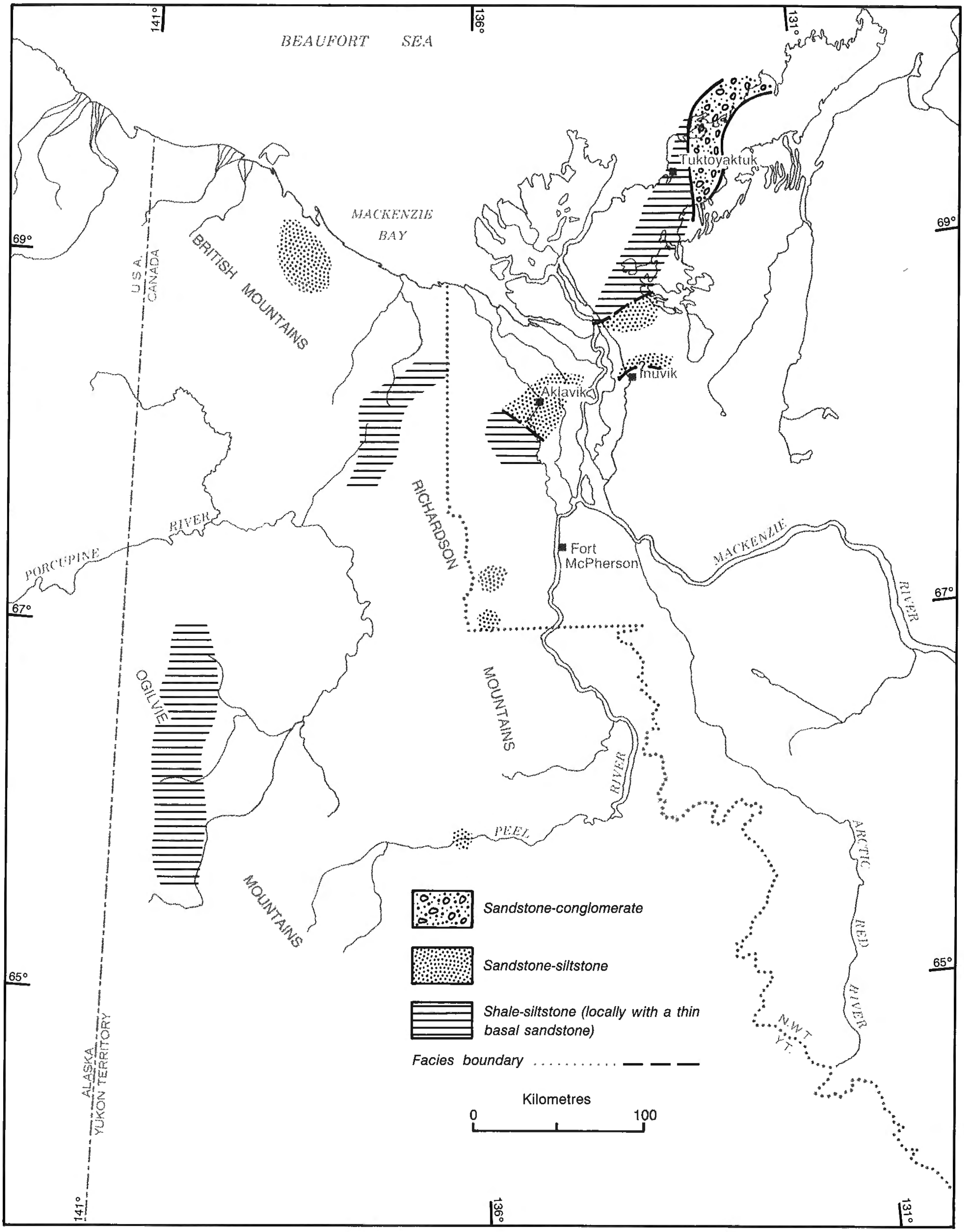

Figure 29. Distribution of the basal facies of the Mount Goodenough Formation.

where it overlies Mount Goodenough strata, but where the top is eroded. Later (Jeletzky, 1960), it was recognized that Albian shales rest abruptly on the formation on the east flank of the Richardson Mountains. Rat River strata are present throughout the northern Richardson Mountains but are absent west of the Rapid Depression. Most of the strata mapped as Rat River Formation in the northernmost Ogilvie Mountains and northern edge of Eagle Plain (Norris, 1981e) are now known to be part of the Albian Sharp Mountain or Porcupine River formations (Dixon, 1986a). No Rat River strata can be identified with certainty in other parts of the Ogilvie Mountains, even though Norris (1982a) mapped their occurrence. Many of the mapped occurrences in the Ogilvie Mountains can be assigned to other units (unpublished field data; Dixon, 1986a). The Rat River Formation is present under parts of southwestern Mackenzie Delta, but becomes progressively siltier and shalier to the northeast, and, in places, appears to have been eroded below a sub-Albian unconformity.

Conglomerates were mapped and identified as Rat River Formation (Jeletzky, 1960; Norris 1981g) along a stretch of the Vittrekwa River (Section 84-3; Fig. 2), but were later reinterpreted as Late Devonian or Carboniferous in age (Jeletzky, 1974, p. 6). The strata at Section 84-3 consist of interbedded conglomerate, sandstone and silty shale arranged into two very large sets of foreset bedding (Fig. 30). These strata are overlain abruptly by interbedded shale, siltstone and thin beds of sandstone of the Martin House Formation. Norris (1981g) indicated that Barremian–Aptian and Fammenian fossils were collected from this site, indicating the ambiguity of dating the conglomeratic unit. The large foreset bedding and sediment gravity-flow characteristics are atypical of Rat River strata seen in the nearby Stony River valley, but are similar to those of rocks at Shiltee Point, 35 km northeast of Section 84-3, that are now known to contain Devonian palynomorphs (McIntyre, pers. comm., 1986). These features of the conglomeratic beds at Section 84-3 add further support to Jeletzky's (op. cit.) identification of a late Paleozoic age.

Norris (1981g) also mapped Rat River strata along the length of the lower reaches of Vittrekwa River (downstream of Section 84-3), and continuing along the banks of the Peel River (Sections 84-2 and 87-24; Fig. 2). Jeletzky (1960) described and identified these beds on Vittrekwa River as the Grey, sandy siltstone member of the Upper sandstone division (i.e., Rat River Formation). Mountjoy and Chamney (1969) indicated that these same beds were part of the Martin House Formation. The beds in the river bluffs consist of grey- and rust-coloured shale, interbedded with thin sandstone beds. An ammonite collected from this succession (Section 84-2, Jeletzky, pers. comm., 1984) indicates an Early Albian age. At a quarry near the Dempster Highway, a few kilometres north of Vittrekwa River, equivalent strata contain a late Aptian ammonite and bivalve assemblage (Section 87-25, Jeletzky, pers. comm., 1988). At nearby Stony Creek the same sequence rests abruptly on typical Rat River sandstone, although Jeletzky (1960) included this sequence in the Upper sandstone division (Rat River Formation). The distinct lithological features, the abrupt lower and upper contacts of the grey and rust-coloured, sandy siltstone and shale beds, the abundance of glauconite, the mapped relationships, and the contained macrofossils and microfossils support Mountjoy and Chamney's (1969) correlation of this sequence with the Martin House Formation.

The Rat River Formation is characterized by interbedded sandstone and shale units throughout its area of occurrence, but there is a general increase in shale westward. In the Mount Goodenough area there is a basal sandstone-dominant interval that tends to form a prominent cliff. These lower beds rest abruptly on Mount Goodenough strata (Fig. 21) and, at Jimmy Creek, at the north end of the Mount Goodenough plateau, they can be seen to crosscut Mount Goodenough beds (Fig. 22). The lower Rat River beds consist of amalgamated hummocky cross-stratified units and are estimated to be about 20 m thick. The orientation of the shallow scour is approximately north-northwest. Gradationally overlying the lower beds is a succession of interbedded sandstone and shale (Fig. 21).

From the Mount Goodenough area southward, across the Eskimo Lakes Fault Zone, the interval between the top of the Rat River Formation and the base of the Mount Goodenough Formation thins dramatically (e.g., between the Aklavik A-37 and Treeless Creek I-51 wells). South of Stony Creek, at the MacPherson B-25 well, there appear to be no Rat River strata and, at Vittrekwa River, Martin House strata rest directly on Paleozoic rocks. At the Stony I-50 well, located between Stony Creek and Rat River, interpretation of the stratigraphy indicates that Rat River strata rest directly on Paleozoic rocks. The implication of these north-to-south relationships, across a major fault zone, is that the Rat River succession south of the fault zone is partly equivalent to the Mount Goodenough Formation (Fig. 32). A similar relationship is seen under Tuktoyaktuk Peninsula in the equivalent-age Atkinson Point

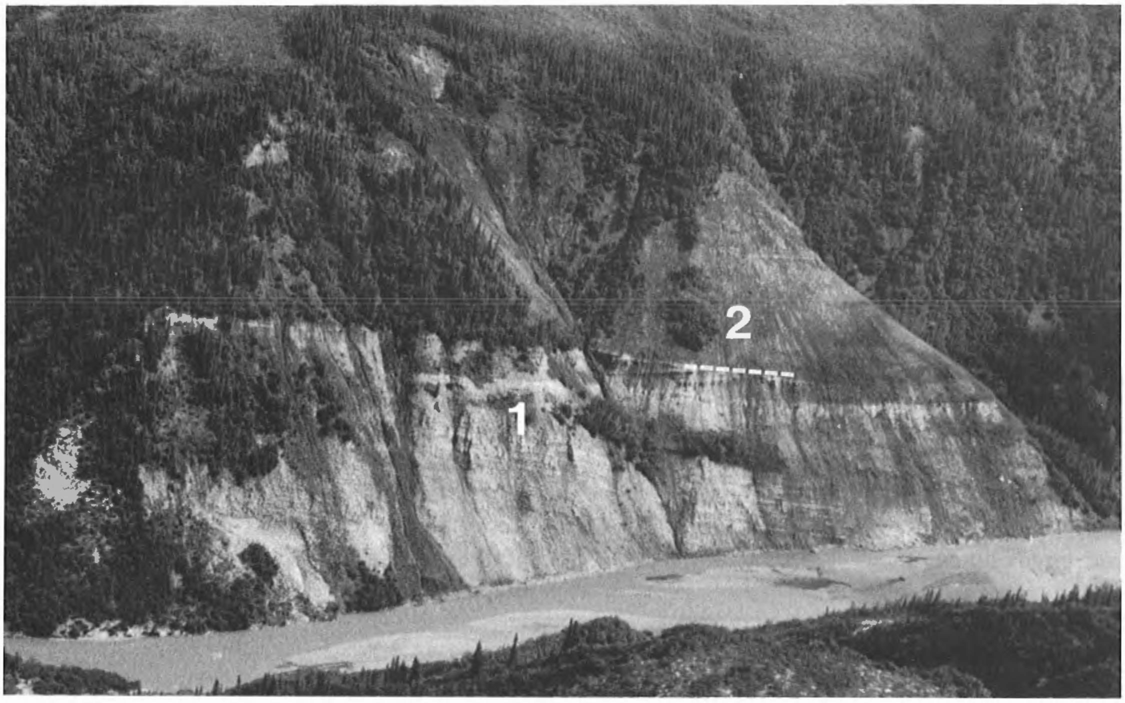

Figure 30. *Large-scale foreset beds in Upper Devonian sediment gravity-flow deposits (1), originally identified and mapped as Rat River Formation (Jeletzky, 1960; Norris, 1981g). The Upper Devonian strata are abruptly overlain by shale and thin sandstone beds of the Martin House Formation (2). Vittrekwa River, Section 84-3. ISPG photo. 1858-25.*

Formation (Fig. 33; Dixon et al., 1989). Also, it would be reasonable to interpret the presence of a depositional edge between Stony Creek and Vittrekwa River, although some truncation of Rat River strata below the Martin House Formation may occur.

Along the banks of Rat River and Stony Creek, the Rat River Formation mostly consists of very fine to fine grained sandstone with some local beds of medium to coarse grained sandstone. In both valleys, coarsening-upward cycles are present. These cycles begin with a thin silty mudstone resting abruptly on underlying sandstone, and grade up through interbedded sandstone and siltstone into a sandstone interval. The sandstone beds contain wave-ripple laminae, rare megaripples, long, low-angle crossbeds (some of which can be traced locally into low amplitude hummocks), and bioturbated beds. Bivalves are locally concentrated along bedding planes.

On the west flank of the Richardson Mountains, Rat River strata consist of two informal members (Jeletzky, 1974; Young 1972): a Lower member, consisting of interbedded shale and sandstone units, and an Upper member, dominated by grey, silty mudstone with numerous thin interbeds of sandstone (the Upper member is the Concretionary, silty mudstone division of Young, 1972). At Fish River, for example (Section 84-8; Figs. 2, 31), the Lower member contains three prominent coarsening-upward cycles and is overlain by the Upper member, which consists of shale with a few scattered sandstone beds. The sandstones in each coarsening-upward cycle are dominated by bioturbated beds, with some beds containing small-scale hummocky cross-stratification and wave ripples. Small-scale planar cross-stratification and *Skolithus*-like burrows have been seen in Rat River strata at other locations on the west flank of the Richardson Mountains (e.g., Section 87-12). Bivalve coquinas also are present in some of the cycles. In the middle to upper reaches of Bell River, Jeletzky (1974) described Rat River strata that appear to be similar in nature to those at Fish River and at Section 87-12, although considerably thicker. Between McDougall Pass and the Dempster Highway, in the Richardson Mountains, Rat River strata consist of from 3 to 8 coarsening-upward cycles in which hummocky cross-stratification is the most common sedimentary structure in the sandstone component. In general, each succeeding cycle becomes more sandy and thicker than the preceding one. Capping the uppermost, and generally most prominent, cycle is an interval of shale with thin sandstone interbeds. Abruptly overlying Rat River strata are shales of a variety of upper Aptian to Albian units (e.g., Martin House Formation, Whitestone River Formation, and Rapid Creek Formation — the actual overlying unit depends upon geographic location). On the east flank of the Rapid Depression, Rat River strata thicken dramatically to 600 m or more (Section 87-12) (Jeletzky, 1974, p. 16).

Depositional environment

The assemblage of sedimentary structures and fossils in the Rat River Formation are evidence of deposition in a marine setting. Hummocky cross-stratification and plane lamination are the most common types of sedimentary structure and indicative of deposition in a high-energy regime, such as major storms. Within the preserved record of the Rat River Formation, evidence of shoreface deposits is limited to the areas along Rat River and Stony Creek. There, the presence of medium to coarse grained sandstone, some rare megaripples, and beds with subparallel lamination suggest proximity to the shoreface. Most of the preserved Rat River Formation appears to have been deposited on the inner to mid shelf, generally below normal wave-base. An increase in the amount of shale interbeds and a higher proportion of bioturbated beds to the west and northwest indicates a more distal relationship to the shoreline in that direction. The large scour at Mount Goodenough has a general north-northwest orientation and may have been formed either by a storm event, or by incision during basin margin uplift of the southwestern end of the Eskimo Lakes Arch. The north-to-south changes in thickness and facies from Mount Goodenough to the Stony Creek area, across the Eskimo Lakes Fault Zone, indicate that the Eskimo Lakes Arch was an active element during Rat River deposition and probably acted as a local shoreline.

Age

The age of the Rat River Formation is considered to be late Barremian to Aptian (Jeletzky, 1958, 1960), based on the identification of bivalve assemblages. One of the more critical fossils is *Aucellina aptiensis*. Foraminifers within the formation are similar to those

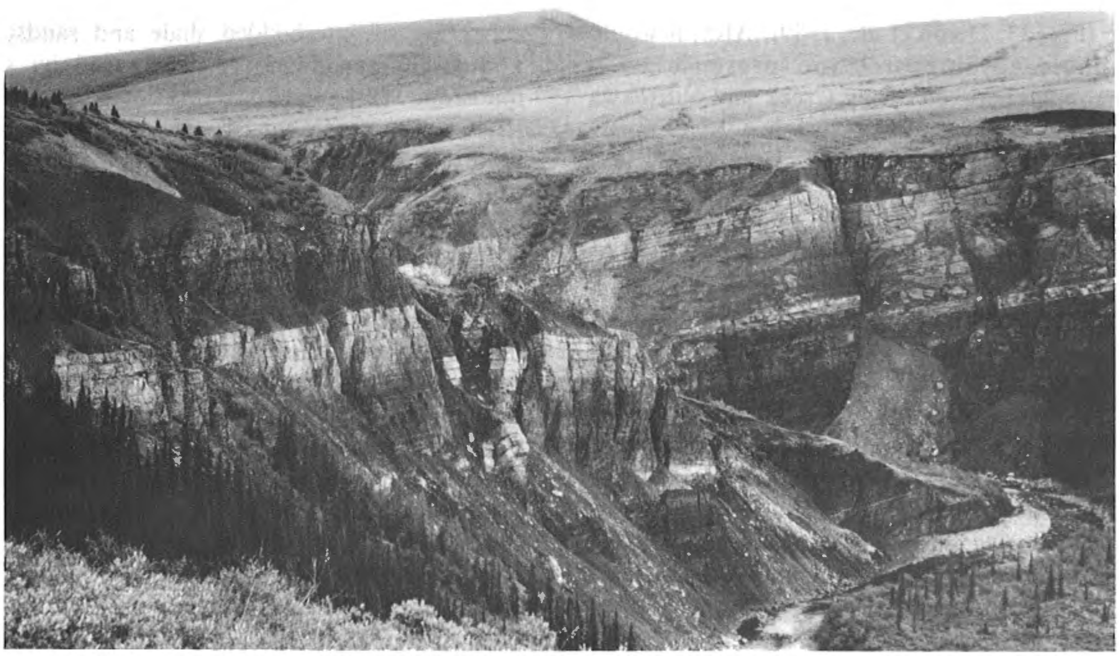

Figure 31. *Coarsening-upward cycles in the Rat River Formation on the west side of Fish River (Sections 84-8 and 87-19). ISPG photo. 2406-10.*

found in the underlying Mount Goodenough Formation and do not appear to be age-diagnostic. Where the base of the formation is a facies boundary, there must be considerable diachroneity. The Rat River Formation in the Stony Creek area appears to be laterally equivalent to both the Mount Goodenough and Rat River interval farther north; consequently, the oldest age for the Rat River Formation in the Stony Creek area could be early Barremian (Brideaux and Fisher, 1976, p. 7).

Atkinson Point Formation

Description

Atkinson Point Formation is the name applied to a succession of conglomerates and sandstones under Tuktoyaktuk Peninsula (Dixon, 1979). Physical correlations and limited paleontological data indicate that it is correlative with the Mount Goodenough and Rat River formations, although it does not appear to form a contiguous sandstone body with the latter (Dixon et al., 1989). Thicknesses up to 120 m are attained, but the unit thins rapidly to the southeast where the zero-edge is a true depositional limit. The formation has a limited areal distribution on the northwest margin of the central Tuktoyaktuk Peninsula.

In the type area, the formation consists of conglomerate overlain by sandstone. Conglomerate content decreases westward, away from the Atkinson wells, and within a few kilometres the formation is completely sandstone. Another few kilometres westward and southwestward, shale and siltstone begin to replace the sandstone in the lower part of the formation. The formation rests unconformably on strata ranging in age from presumed Proterozoic or Early Cambrian to Cretaceous at its southern limits, but the lithostratigraphic base rises as a facies front to the west and southwest, as sandstone is laterally replaced by shale and siltstone (Fig. 33).

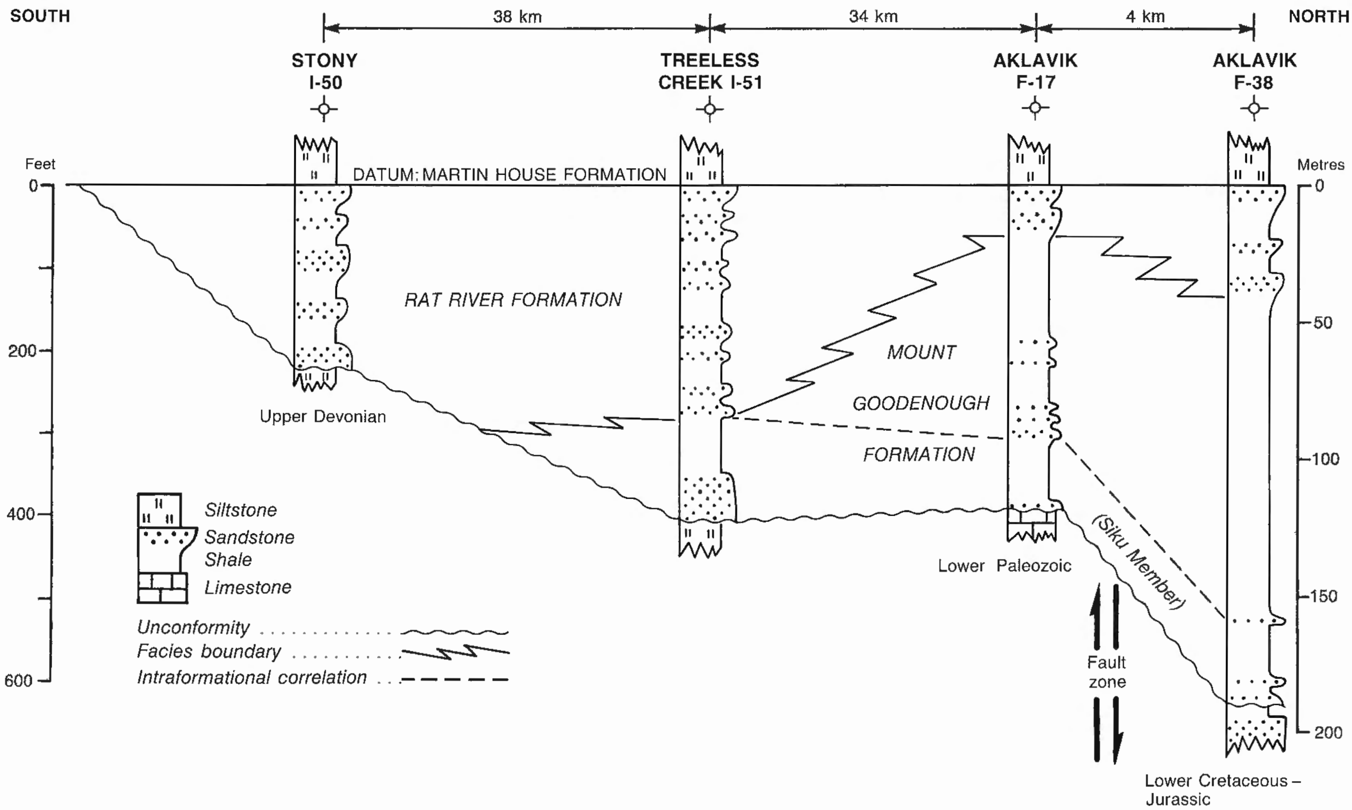

Figure 32. Correlation diagram for Mount Goodenough and Rat River strata across the Eskimo Lakes/Trevor fault zone, based on the Stony I-50, Treeless Creek I-51, Aklavik F-17, and Aklavik F-38 wells. The lithological succession in the Aklavik F-38, F-17, and Treeless Creek I-51 wells was determined from cutting samples and gamma-ray/SP log response. The Stony I-50 well was drilled as a small diameter, continuously cored borehole.

Dixon (1979) described in detail the facies and sedimentary structures of the Atkinson Point Formation. Briefly, the formation contains beds of conglomerate, conglomeratic sandstone and sandstone. Conglomerate beds are massive to crudely bedded and some have imbricated clasts. Sandstone beds may be structureless, finely laminated, low-angle cross-stratified, and, in the more westerly occurrences, they are burrowed to burrow mottled.

Depositional environment

Based on the distribution of facies and the sedimentary structures Dixon (1979) concluded that the Atkinson Point Formation was deposited as a small coastal fan-delta. The conglomerates and conglomeratic sandstone beds were interpreted as having been deposited in braided channels on the subaerial fan-delta. Some of the conglomerate-sandstone and most of the sandstone beds were deposited at the delta front and on the submarine part of the delta. A transgression ended Atkinson Point deposition and some of the thin sandstone units identified as Atkinson Point Formation, to the northeast and south of the Atkinson wells, probably represent only the transgressive phase of deposition.

Age

The age of the Atkinson Point Formation is not firmly established from the sparse indigenous fauna and flora. Chamney (1972, and *in* Barnes et al., 1974) suggested an Aptian to Early Albian age, based on foraminifers collected from several cores within the formation. The overlying shales of the Arctic Red Formation contain Early Albian fossils in both outcrop and subsurface, limiting the upper age of the Atkinson Point Formation. Physical correlations suggest that it is laterally equivalent to the Mount Goodenough and Rat River formations (Dixon et al., 1989), indicating that it is probably Barremian to Aptian in age, but could be as young as Early Albian.

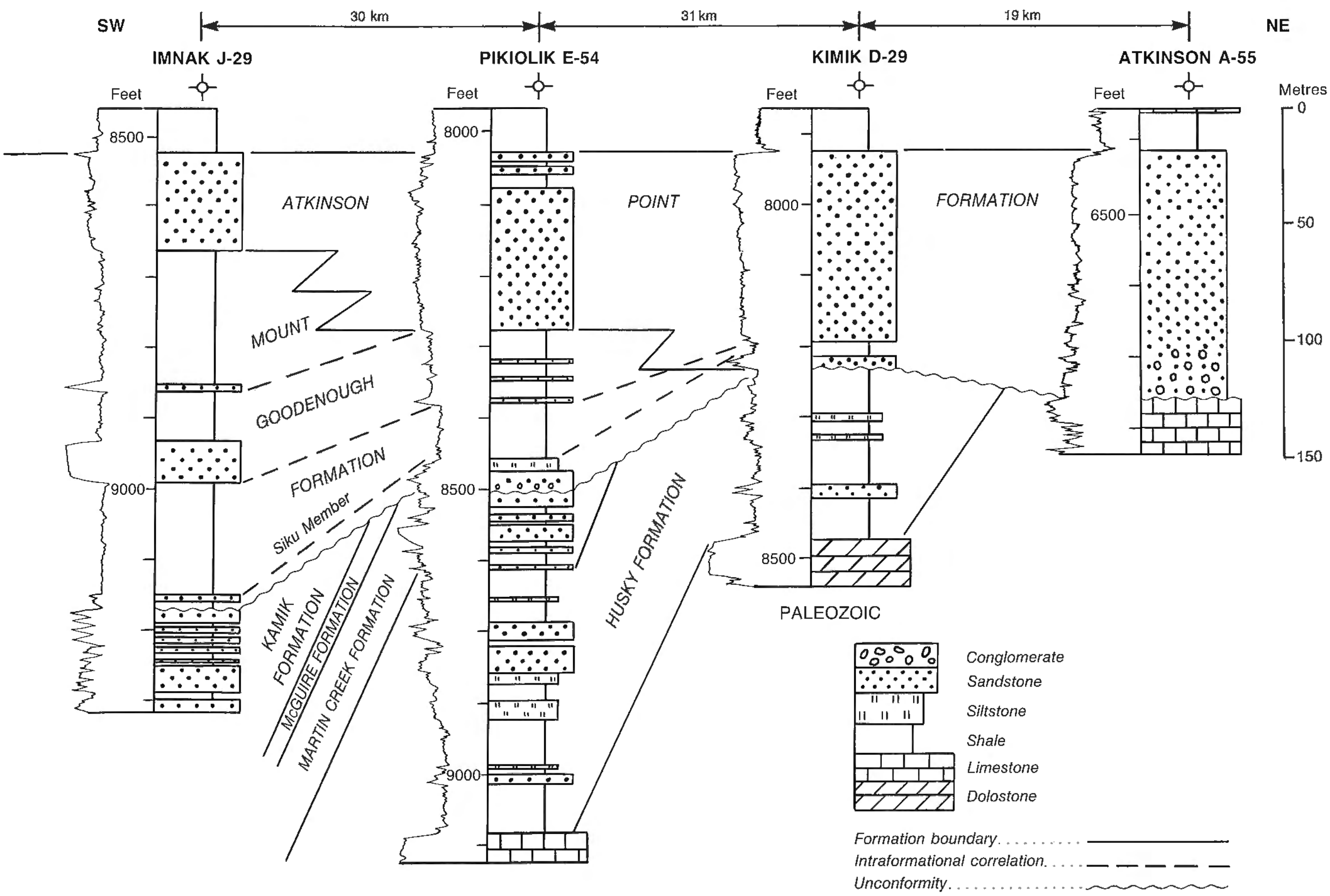

Figure 33. Correlations and facies changes within the Atkinson Point Formation under Tuktoyaktuk Peninsula (gamma-ray logs).

Martin House Formation

Description

Martin House strata were defined and described by Mountjoy and Chamney (1969) from the area where the Snake River joins the Peel River, and were identified as far north as Satah and Vittrekwa rivers (although Norris, 1981g, mismapped these strata as Rat River Formation; see above discussion in the section on the Rat River Formation). Two informal members were identified in the type area, a Basal siltstone member, overlain by the Glauconite member. The base of the Basal siltstone member was not seen in outcrop, but in nearby wells it rests on Paleozoic strata, mostly Carboniferous. About 21 m of the Basal siltstone member were measured. According to Mountjoy and Chamney (op. cit.) the Glauconite member gradationally overlies and overlaps the Basal siltstone member. Because of the overlap the Glauconite member was recognized over a larger area than the underlying member, as far north as Vittrekwa River (Mountjoy and Chamney, op. cit.), although equivalent strata have been seen as far north as Stony Creek (pers. observation, 1987). The upper contact of the Glauconite member was not specifically referred to in Mountjoy and Chamney (op. cit.), but their discussion and diagrams imply a gradational contact with the Arctic Red Formation. At Vittrekwa River, where strata previously identified as Rat River Formation are typical Martin House strata, the contact is abrupt (Fig. 34). In the type area the Glauconite member is about 104 m thick.

The Basal siltstone member consists of interbedded siltstone and silty shale, with some concretion horizons. The Glauconite member consists of interbedded fine grained sandstone, siltstone and shale. Glauconite is a common component of the member and imparts a greenish hue to some of the rocks. However, a rusty brown colour is prevalent. Sandstone and siltstone content decreases to the north and east of the type area, and, at its known northern limits, the member is mostly silty shale with some thin glauconitic sandstone beds. Near where Satah Creek joins Peel River, the Glauconite member rests on a conglomerate that was thought to be either Albian or Carboniferous by Mountjoy and Chamney (1969, p. 9, 11). This location is close to Vittrekwa River where Martin House strata overlie Upper Devonian conglomerates (see section on Rat River Formation); consequently, the Satah River conglomerate also is considered to be Upper Devonian. There are local variations in the character of the Glauconite member (Mountjoy and Chamney, op. cit., p. 9); usually variations in the content of sandstone, shale, glauconite, or concretions. At Vittrekwa River, several thin (2 to 3 m) coarsening-upward units have been identified in beds equivalent to the Glauconite member (Section 84-2; Figs. 2, 34). The coarsening-upward units are capped by about 0.5 to 1 m of very fine to fine grained, horizontally laminated and hummocky cross-stratified sandstone, in turn capped by a thin coquina of bivalves. However, the bulk of the formation consists of brownish weathering shale with concretions. The contact with the overlying medium to dark grey shales of the Arctic Red Formation is abrupt.

The Martin House Formation overlies progressively older strata from north to south. At Stony Creek it rests on the Aptian Rat River Formation and, 19 km to the south, at Vittrekwa River it rests on Upper Devonian rocks. The northern extent of Martin House strata is not known, owing to inadequate exposures.

Depositional environment

The lithology of, and the abundance of marine fossils in Martin House strata indicate deposition in a shelf environment, while the presence of hummocky cross-stratified sandstones and coquinas is indicative of deposition during storm activity. Martin House strata are interpreted as representing deposition during the late Aptian/Early Albian transgression, recorded elsewhere in northern Canada.

Age

The age of the Martin House Formation was identified by Chamney (*in* Mountjoy and Chamney, 1969) as questionably Aptian to Early Albian, based on foraminifers. The Basal siltstone member was tentatively dated as Aptian and the Glauconite member as possibly Aptian to Early Albian. The Early Albian age is more firmly established, based on the presence of Early Albian ammonites: *Beudanticeras* in the upper part of the Glauconite member (Mountjoy and Chamney, op. cit., p. 10), and *Pachygrycia canadensis* from lower strata (Jeletzky and Stelck, 1981, p. 11). Also, Jeletzky (pers. comm., 1984) identified an Early Albian ammonite (*Pachgrycia* or *Cymahoplites*) from equivalent strata at Vittrekwa River. An ammonite, identified as *Tropaeum,* and bivalves of the species *Aucellina aptiensis* were collected from Martin House strata in a quarry near the Dempster Highway (Locality 87-25; Jeletzky, pers. comm., 1988), both of

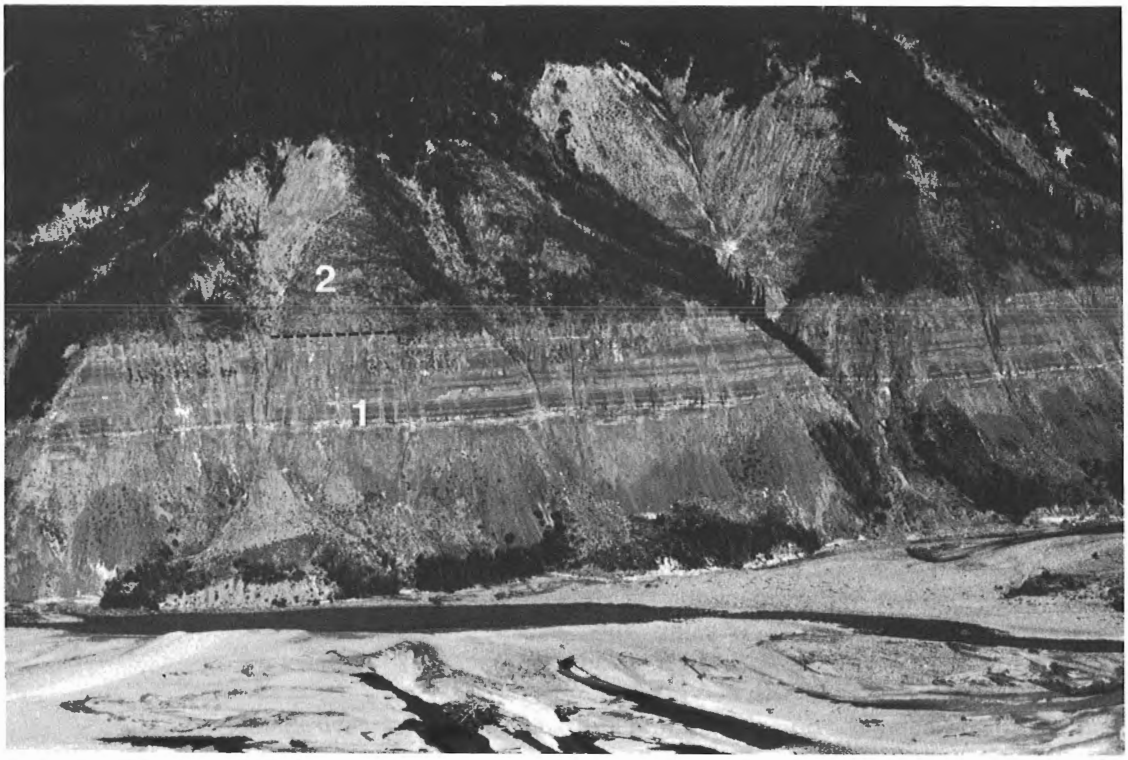

Figure 34. Beds equivalent to the Glauconite member of the Martin House Formation (1) at Vittrekwa River (Section 87-24). These beds contain small-scale coarsening-upward units and are abruptly overlain by grey shale of the Arctic Red Formation (2). ISPG photo. 2846-8.

which suggest a late Aptian age. From the available paleontological data the Martin House Formation appears to be late Aptian to earliest Albian in age.

Arctic Red and Horton River formations

Description

The Arctic Red and Horton River formations are Albian shale-siltstone units present on the Peel Plateau and Anderson Plains respectively. Norris (1981d, g, h) used the Mackenzie River as the dividing line between the two formations. West and south of the river he mapped the shales as Arctic Red, north and east, he mapped them as Horton River. Young et al. (1976, p. 21, 22, fig. 9) suggested that the Arctic Red and Horton River formations could be differentiated on the basis of more bentonite interbeds in the Horton River Formation. Using this criterion he limited the Horton River Formation to the Anderson Plains, and identified the transition into Arctic Red strata as the southeast flank of the Eskimo Lakes Arch. For the purposes of the present discussion, all Albian shale units east of the Richardson Mountains and within the eastern boundary of the Operation Porcupine map area will be referred to as Arctic Red Formation.

Chamney and Mountjoy (1969) defined the Arctic Red Formation from the area of Snake, Peel, and Arctic Red rivers. They also recognized that locally it occurs below the Trevor Formation but, in other areas, it is laterally equivalent to part of the Trevor Formation. Also, they recognized its correlation with Jeletzky's (1960) informal Albian shale-siltstone division on the east flank of the Richardson Mountains. Norris (1981g) mapped the Albian shale-siltstone division as Arctic Red Formation.

At the type area, the Arctic Red Formation overlies the Glauconite member of the Martin House Formation and is gradationally succeeded by the Trevor Formation. North and northeast of the type area the Trevor Formation grades laterally into shales of the Arctic Red Formation. Concretionary shales and silty shales were identified as the two principal facies types in the formation (Mountjoy and Chamney, 1969). Using these basic facies types, Mountjoy and Chamney (op. cit.) recognized a number of local informal members, based on their observation that silty shale units are present in the more southerly areas and concretionary shales in the northern areas. Rocks of the silty shale facies are characterized by thin bedded, dark grey to brown shale and interbeds of siltstone. Concretions and clay (?bentonite) beds are also present. The concretionary shale facies is characterized by dark grey to black shale with numerous concretions (some of which are up to 1.2 m in diameter). Layers of soft clay are locally present and may be bentonite beds. In the type area the Arctic Red Formation is between 350 and 400 m thick.

North of the type area the Arctic Red Formation rests abruptly on the Glauconite member of the Martin House Formation, although, where the latter cannot be recognized, upper Aptian and Albian strata that are identified as Arctic Red Formation, abruptly rest on older strata. Where the Arctic Red Formation rests directly on pre-Albian strata, basal beds are locally silty to sandy, and lag conglomerates are known in a few places. The thickness of these basal beds is highly variable, from a few centimetres to several tens of metres. For example, a few kilometres south of Campbell Uplift, Arctic Red strata rest unconformably on the Devonian Imperial Formation and there are several metres of thinly bedded, very fine to fine grained, horizontally to crosslaminated sandstone and shale (Section 85-24; Fig. 35). These basal sandy beds may be equivalent to the Glauconite member of the Martin House Formation. Under northern Tuktoyaktuk Peninsula, Arctic Red strata contain at least one radioactive interval (marker F of Myhr, 1975), which may be a bentonite-rich interval.

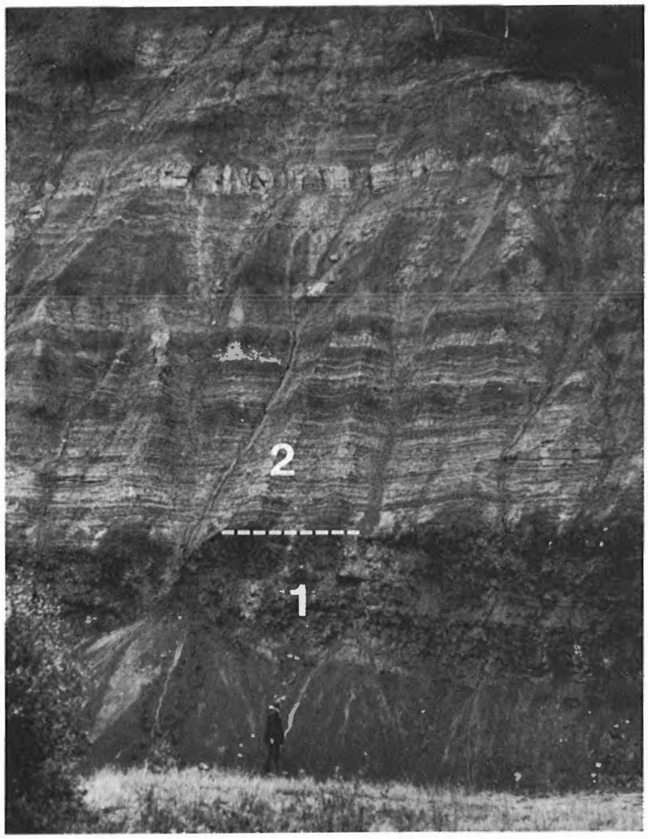

Figure 35. Basal sandy beds of the Arctic Red Formation (2), unconformably overlying the Devonian Imperial Formation (1) near Campbell Lake (Section 85-24). ISPG photo. 2584-5.

In the Kugmallit Trough, which lies on the northwestern flank of the Eskimo Lakes Arch, a thick (1000 m) succession of Arctic Red strata is divisible into three informal members (Dixon et al., 1989). The Lower member is a thin (about 100 m), organic-rich shale unit and is overlain by a thicker (up to 600 m) silty shale succession of the Middle member. Reflection seismic data reveal that the Middle member is a prograding succession consisting of slope clinoforms. Onlapping the Middle member are shales of the Upper member, the lowermost beds of which are also organic-rich. The Upper member can be in the order of 600 m thick, but pre-Late Cretaceous erosion has removed it from some areas.

Depositional environment

With the exception of the local basal sandy beds the bulk of the Arctic Red Formation south of the Eskimo Lakes Fault Zone was deposited in a generally low-energy marine environment, probably mid to outer shelf. The basal sandy beds appear to represent deposition during a late Aptian to Early Albian transgression and are higher energy marine deposits, commonly associated with local topographic highs along the plane of transgression on the Eskimo Lakes Arch. These basal sandy beds are probably equivalent to the Martin House Formation, but, because of their apparent lack of physical continuity with Martin House strata, they are included in the Arctic Red Formation. Within the Kugmallit Trough, slope and basinal conditions prevailed.

Age

The age of the Arctic Red Formation, at its type section and nearby locations, was given as Early to Late Albian by Mountjoy and Chamney (1969). Dating was based primarily on foraminifers and a few ammonites. Similar ages have been cited for the Arctic Red Formation in its northern occurrences, although Late Albian ages are not well documented (Jeletzky, 1960; Chamney, *in* Brideaux et al., 1975; Brideaux, *in* Barnes et al., 1974; Dixon et al., 1989). Albian strata generally have a rich and varied microfauna, and ammonites also are locally common; this allows for more precise dating than is possible for some of the underlying Cretaceous strata. The lack of identified Upper Albian strata throughout much of the study area can be attributed to Late Albian/Early Cenomanian erosion. However, within the Kugmallit Trough the Upper member of the formation contains pollen and dinoflagellates that indicate a Late Albian age (Dixon et al., 1989).

Trevor Formation

Description

In the study area, Trevor Formation strata are present in the Trevor Range, south and east of the junction of Peel and Snake rivers. They extend eastward as far as Norman Wells (Mountjoy and Chamney, 1969; Yorath and Cook, 1981). Mountjoy and Chamney (1969) named the formation and designated Cranswick River as the type area. They estimated that there are about 360 m of Trevor strata, whereas Yorath and Cook (1981) measured up to 1152 m on Hume River.

The Trevor Formation gradationally overlies Arctic Red strata and a diachronous lower boundary is evident (Yorath and Cook, 1981). In the western areas of its occurrence, strata of the Trevor Formation are the youngest exposed, whereas, in the easternmost areas, Yorath and Cook (op. cit.) noted that the Trevor Formation grades laterally into the shale-dominant Slater River Formation and is locally overlain by the Little Bear Formation.

Lithologically, the formation consists of interbedded sandstone and shale. Sandstones are generally fine grained, locally pebbly, and occur in thin to medium beds. Pebbles are mostly chert and ironstone. Ripple crosslamination and load casts are common. Carbonaceous debris and plant fragments are present on many bedding planes. Marine bivalves and gastropods have been collected from some sandstone beds.

Depositional environment

The presence of marine fossils, thin beds, abundance of ripple marks, and interbedding with shale suggest deposition in a shelf environment, possibly inner shelf. A lack of more detailed descriptions of sedimentary structures and facies changes precludes a detailed sedimentological interpretation.

Age

Poor fossil recovery and the presence of long-ranging microflora do not provide good age control. Mountjoy and Chamney (1969) cited identifications of some macrofossils by J. Jeletzky as indicating a Late Albian age for the lower Trevor Formation in the Trevor Range. Yorath and Cook (1981) suggested that the formation ranged from Late Albian to Cenomanian. However, their interpretation is based on microflora that have a known range of Late Albian to Cenomanian, and their data are not definitive, therefore, of a youngest age. Aitken et al. (1982) reported the occurrence of Cenomanian and Turonian species of *Inoceramus* from the upper beds of the Trevor Formation, a more reliable definition of its youngest limits.

Rapid Creek Formation

Description

The Rapid Creek Formation is a phosphatic iron formation located on the northwestern rim of the Richardson Mountains (Young and Robertson, 1984). It is up to 1000 m thick but thins rapidly eastward, on to the Cache Creek Uplift, where it is as thin as 60 m along Fish River. On the Cache Creek Uplift it rests erosionally on older strata, but westward it becomes conformable with other Albian strata. At its type area it is overlain unconformably by the Upper Cretaceous Boundary Creek Formation.

Because of the unusual phosphatic lithology of the formation, Young and Robertson (1984) used a modification of Dunham's (1962) scheme for classifying carbonate rocks. Rock types such as phosphate grainstone, packstone, mudstone and wackestone were identified, interbedded with shale, siltstone and conglomerate. Correlations by Young (1972) and Young and Robertson (op. cit.) show that the phosphatic beds grade laterally westward into non-phosphatic clastic rocks of the informally named Albian flysch.

Depositional environment

The Rapid Creek Formation is located between the shelf sediments of the Arctic Red Formation to the southeast and the basinal sediment gravity-flow deposits of the Albian flysch to the west. This location would indicate that it was deposited in an outer shelf to slope environment. Young and Robertson (1984) suggested that the phosphatic material may have been derived from a cold, northeast-flowing current upwelling along the western flank of the Cache Creek Uplift. Yeo (1990) concluded that the phosphatic material formed during an oceanic anoxic event.

Age

Macro- and microfossils are poorly preserved in the Rapid Creek Formation; however, the few ammonites and bivalves found indicate an Early Albian age (Young and Robertson, 1984, p. 368). The ammonite *Pachygrycia* (originally identified as *Sonneratia*) and the bivalves *Inoceramus anglicus* and *Pholadomya* have been identified from the Rapid Creek Formation. The age of the Rapid Creek Formation suggests it is coeval with either the upper part of the Martin House Formation or the basal part of the Arctic Red Formation.

Albian flysch

Description

Within the Rapid Depression (Blow Trough of Young et al., 1976) there is a thick (at least 4000 m) succession of basinal deposits that have been informally referred to as the Aptian–Albian flysch, or more succinctly as the Albian flysch (Jeletzky, 1971a, 1975b; Young, 1972, 1977). Norris (1981c) mapped two units within the Albian flysch, informally designated Ksr (a conglomerate and sandstone unit) and Kbr (predominantly shale but with variable amounts of interbedded sandstone and conglomerate), whereas Young (1977) mapped at least four units in the area of Blow and Rapid rivers. Both Jeletzky and Young considered that the flysch succession gradationally succeeded Rat River, or equivalent, strata. However, on Cache Creek Uplift and on the western flanks of Rapid Depression the Albian flysch strata rest erosionally on older strata (Young, 1977; Young and Robertson, 1984; Norris, 1981c). Elsewhere in the study area, Albian flysch strata tend to rest abruptly on older rocks; consequently, this boundary may be a fundamental break in the stratigraphic record and the gradational contact recorded by some authors may not exist.

The succession is dominated by interbedded shale, siltstone, and sandstone with locally thick intervals of conglomerate and sandstone (unit Ksr of Norris, 1981c). In the centre and eastern flank of Rapid Depression, Young (1972) mapped a series of local, informal units, which are, in upward vertical succession: lower mudstone unit, conglomerate and sandstone or turbidite unit, brittle silty mudstone unit, and bedded ironstone and shale unit. The last unit now would be considered part of the Rapid Creek Formation (Young and Robertson, 1984). Young (1977) recognized that the lithological succession in the Albian flysch involved complex vertical and lateral facies changes. On the western flank of Rapid Depression, a conglomerate-dominant interval (Section 87-17; on a prominent mountain known as "The Twins") rests either unconformably on older Cretaceous strata, or overlies a thin basal Albian shale that rests unconformably on older strata. In the centre of the depression the basal mudstone is overlain by up to 610 m of sandstone and conglomerate (Fig. 36) (map unit Ksr of Norris, 1981c). Northward and northeastward of the conglomerate and sandstone unit, laterally equivalent strata consist of interbedded sandstone, siltstone, and shale in which Bouma sequences are present (Fig. 37). Conglomeratic beds are locally present in the shale-dominant successions but are not abundant. The amount of interbedded sandstone tends to decrease east and north of the conglomerates; such that, under the coastal plain, the bulk of the Albian succession is mudstone and shale with thin interbeds of very fine grained sandstone (e.g., at the Blow River YT E-47 well). The conglomerate and sandstone unit also is overlain by a shalier succession.

Pebbles in the conglomerate beds are mostly chert, with lesser amounts of quartzite, granodiorite, and gneiss. Most of the conglomerates contain small, well rounded pebbles, generally less than 4 cm in diameter. Larger clasts, up to 50 cm, are locally present but not common. Because of the dominance of small pebbles, individual beds in thick conglomerate intervals tend to be poorly defined.

Depositional environment

The Bouma-type sequence of sedimentary structures in sandstone beds, and locally developed massive conglomerates, point to an origin for the Albian flysch as sediment gravity-flow deposits in a basinal setting (Young, 1972, 1973a, b, 1977). A western source, which Young et al. (1976) identified as the Brooks Range Geanticline, for the coarser clastics is indicated by the general easterly and northerly fining trend within the Albian succession.

Age

Fossils are scarce in the flysch sequence but the few ammonites found indicate an Early to Middle Albian age (Jeletzky, 1960, 1971a). To date there has been no report of Late Albian fossils from the flysch sequence. The Aptian age cited by Jeletzky (op. cit.) and Young (op. cit.) appears to be based on Jeletzky's (1971a) identification of Aptian strata in the Bonnet Lake/Blow Pass area, which he identified as the lowest beds of the flysch succession. However, in a later publication (Jeletzky, 1975b), he recorrelated his 1971 lowermost unit with the Mount Goodenough Formation (Upper shale-siltstone division). The Aptian age for the lowermost beds of the flysch sequence does not appear to be based on firm paleontological or stratigraphic data, although when viewed on a regional basis a late Aptian age may be possible.

Sharp Mountain Formation

Description

The Albian conglomerate and sandstone Sharp Mountain Formation (Jeletzky, 1975a) is present in the mountains bordering the northernmost part of Eagle Plain (Fig. 6). Dixon (1986a) identified additional outcrops of the formation and recognized that much of the strata previously mapped as Rat River Formation (Norris, 1981e) in the Keele Range and northernmost Ogilvie Mountains is actually Sharp Mountain Formation. Sharp Mountain strata rest erosionally on a variety of older units, ranging in age from Jurassic to Barremian. At the type locality, an Albian shale-dominant succession (map unit Kwr of Norris, 1981e; the Whitestone River Formation of Dixon, in press a) abruptly overlies it, not faulted as mapped by Norris (op. cit.). At the type area the formation is between 700 and 900 m thick.

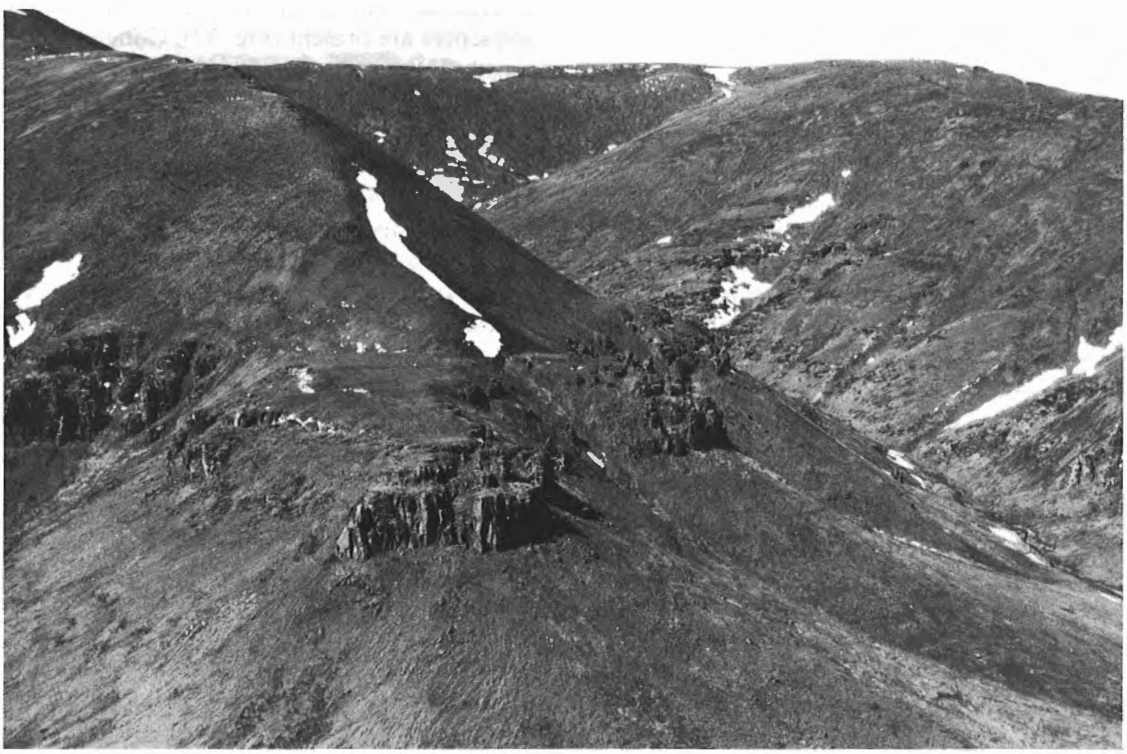

Figure 36. *Conglomerates of the Albian flysch, at the headwaters of Purkis Creek (Section 87-12). ISPG photo. 2584-4.*

Conglomerate-dominant and sandstone-dominant intervals are present throughout the Sharp Mountain Formation, and, southwest of the type area, shale-dominant units become more common. Conglomerates are generally massive, only rarely is there visible internal stratification. Clasts are mostly well rounded chert pebbles, generally less than 2 cm in diameter. Sandstones also tend to be without visible structures, although horizontal laminae are relatively common, and in some locations ripple laminae are present. The shale-dominant units contain thin beds of siltstone and very fine grained sandstone, and locally there are mud-supported conglomerates.

Depositional environment

Jeletzky (1975a) originally interpreted the Sharp Mountain beds as shallow-marine deposits. Dixon (1986a), however, reinterpreted them as sediment gravity-flow deposits, similar in many respects to the coeval conglomerates of the Albian flysch sequence to the north, in the Rapid Depression. The distribution of the Sharp Mountain conglomerates and the southward fining trend indicate a northerly to northwesterly source terrane.

Age

Fossils are scarce in the Sharp Mountain Formation, but sufficient ammonite fragments were recovered by Jeletzky (1975a; Jeletzky and Stelck, 1981, p. 11) for him to date the formation as Early Albian. Microfossils from some of the shale units in the formation also indicate an Early to Middle Albian age (McNeil, pers. comm., 1985).

Kathul Formation

Description

In Kandik Basin there is a succession of conglomerate and sandstone that Norris (1982a) correlated with the contiguous Kathul Graywacke on the Alaskan side of the basin (Brabb, 1969). These are the youngest bedrock strata present in the basin. Exposures are reasonably good along the eastern basin margin but become poorer in the basin centre. Consequently, the complete stratigraphy and thickness is unknown. Jeletzky (1971a) estimated that upward of 1524 m could be present. However, there is considerable folding and minor thrust faulting within

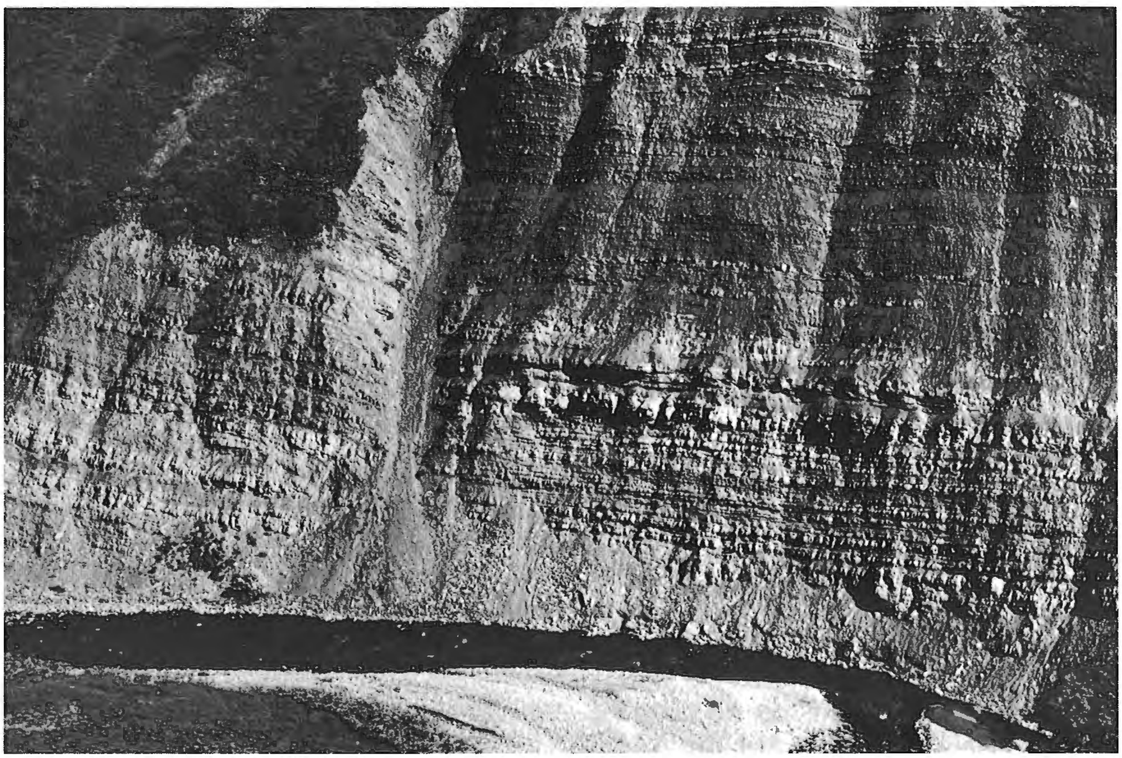

Figure 37. Interbedded sandstone and shale, with some conglomerate beds, in the Albian flysch at Ladas Creek (Locality 87-25). ISPG photo. 2846-9.

the basin, so that even an approximate estimate is subject to much error. Two continuous, but incomplete, sections of Kathul strata were measured in 1986, the thickest containing 878 m of strata (Section 86-20).

On the eastern edge of Kandik Basin Kathul strata rest upon dark grey to black shales of the Mount Goodenough Formation. Although the contact was not exposed, it is apparent from the field relationships that the contact is structurally conformable. There is a distinct and abrupt colour change between the Mount Goodenough shale and the overlying basal shale of the Kathul Formation. The known Kathul succession consists of a basal shale-dominant interval that is 194 m thick at Section 86-20, gradationally overlain by a succession of interbedded sandstone and conglomerate that is at least 684 m thick (Fig. 38). Intercalated with the basal shales are thin (generally less than 10 cm) beds of sandstone and pebbly sandstone. The shale is very fissile, weathers a lighter hue than the underlying, siltier, Mount Goodenough shale, and tends to have a slight rust coloured tint.

Within the sandstone–conglomerate succession, sandstone-dominant and conglomerate-dominant units alternate. Individual beds are difficult to identify, although some indications of internal erosion surfaces and normal grading within the conglomerates and pebbly sandstones point to amalgamated beds within the thick units. Sedimentary structures are uncommon and where seen are invariably in fine to medium grained sandstone, and consist of current ripples and low-angle to subhorizontal lamination. Conglomerates mostly contain small pebbles (less than 4 cm in diameter), although large boulders up to 30 cm were noted. The clasts are predominantly black and brown chert, and lesser amounts of quartzite. A distinctive grass-green chert occurs in some beds. Sorting within the conglomerates is variable, although there is a tendency for good sorting in the small-pebble conglomerates. Normal, and some inverse, grading are present but not common. The conglomerates are mostly clast supported, although a few beds in the basal shale interval, and other mud-rich intervals, are matrix supported.

Depositional environment

Beds of the Kathul Formation are very similar to the coeval Sharp Mountain Formation and the Albian flysch of northern Yukon. The strata have all the attributes of sediment gravity-flow deposits: poorly defined bedding in the conglomerates, generally thinly bedded sandstones, normal and inverse grading, and a few matrix supported conglomerates. The source of the detritus could not be ascertained, owing to the scarcity of oriented, current-generated structures. In the Alaskan part of Kandik Basin, Howell and Wiley (1987, p. 624) reported paleocurrents directed to the east-northeast, which would be consistent with a westerly or southwesterly source from the ancestral Brooks Range foldbelt.

Age

No microfossils or macrofossils were recovered from Kathul strata in Yukon, nor did Brabb (1969) find any age-diagnostic fossils in Alaska. Brabb (op. cit.) assigned an Albian age to the Kathul Formation, based on stratigraphic relationships. On the Canadian side of Kandik Basin, Kathul strata overlie shales that contain a typical Mount Goodenough foraminiferal assemblage (S. Fowler, pers. comm., 1986). Consequently, the Kathul has to be younger than Barremian, and possibly younger than Aptian. The Kathul succession is very similar to that seen in the better dated, Early Albian Sharp Mountain

Figure 38. *The Kathul Formation in Kandik Basin (Section 86-6); a lower shale interval (1) is overlain by a sandstone and conglomerate succession (2). Section 86-6. ISPG photo. 2619-3.*

Formation and Albian flysch, and a direct correlation is almost certainly correct.

Whitestone River Formation

Description

Surrounding and underlying Eagle Plain, in the western Keele Range, Ogilvie Mountains and Bell River drainage basin, Norris (1981e, f, i, j) mapped an unnamed Albian unit (Kwr), which I (Dixon, in press a) have named the Whitestone River Formation. Whitestone River strata are poorly exposed at surface in Eagle Plain and the western occurrences, and are best known from the subsurface, under Eagle Plain. There, the Molar YT P-34 well (Fig. 2) penetrated about 1480 m of Albian strata, and eight cores, cut throughout the formation, are representative of the unit. The succession is dominated by dark grey to black shale, interbedded and interlaminated with siltstone and very fine grained sandstone. The siltstone–sandstone beds are a few millimetres to several centimetres thick, but rarely exceed 4 cm in thickness. Fine, subhorizontal and current-ripple lamination is the most common sedimentary structure. Ripple forms commonly exhibit load deformation. The beds of coarse clastic material invariably have abrupt basal and upper contacts with the enclosing shale. The frequency of occurrence of siltstone–sandstone interbeds varies throughout the formation, and, although sand/silt-rich intervals can be identified in individual wells, they do not appear to be correlatable over any great lateral extent between wells. Most of the wells on Eagle Plain penetrated Whitestone River strata and the lithology is similar to that in Molar YT P-34. However, along the southern edge of Eagle Plain, outcrops of Whitestone River Formation indicate a subtle change in character, with more fissile shale and less interbedded sandstone.

Under Eagle Plain, Whitestone River strata rest abruptly on Sharp Mountain strata in the north, and unconformably on older rocks farther south. The lateral relationships between the Sharp Mountain Formation and the basal Whitestone River Formation are not known with certainty, but it is assumed that the former passes laterally into the shale-dominant Whitestone River Formation. On the west flank of the Richardson Mountains, Whitestone River shales rest abruptly on the upper beds of the Rat River Formation. There, the basal, rusty weathering, brittle shales of the Whitestone River Formation contain a few bentonite beds, one millimetre to one centimetre thick.

Depositional environment

Whitestone River strata contain abundant microfossils and some ammonites (Jeletzky and Stelck, 1981), attesting to their marine origin. The formation may be laterally equivalent (at least its lower part) to the Sharp Mountain Formation, and some of the Whitestone River Formation probably represents sedimentation on the distal parts of submarine fans and in the basin plain. Many of the thin siltstone–sandstone beds appear to be have been deposited from low-density turbidity currents. Such deposits could have formed in slope and outer shelf environments, as well as basin plains. In the southern part of Eagle Plain, the character of the Whitestone River Formation suggests that the shales in this area were deposited in a shelf environment. Regional thinning to the south and southeast, and the southward facies change to sandier beds seen in the equivalent Arctic Red/Trevor formations, also favour a south-to-north change from shelf to deep water.

Age

Very little paleontological data are available from outcrops of the Whitestone River Formation, most data are from the wells drilled on Eagle Plain. There, foraminifers recovered from the Molar YT P-34 well have an Early to Middle Albian age range (Chamney, in Norford et al. 1971). Jeletzky (1960) collected Albian macrofossils from an outcrop of Whitestone River Formation on Porcupine River. Probable equivalent strata in the Waters River area, northeast of Eagle Plain, contain Early Albian ammonites (Young, 1975b; Jeletzky and Stelck, 1981, p. 10).

Monster Formation

Description

Strata of the Monster Formation are present in the southwestern corner of the study area, in the vicinity of the upper reaches of Tatonduk River, and are best exposed in the core of the Monster Synclinorium. Mountjoy (1967) named the formation, although Green and Roddick (1962) had mapped it earlier as an unnamed unit (their map unit 22). Ricketts (1988) made detailed stratigraphic and sedimentological studies of the formation. Green and Roddick (op. cit.) estimated that there are 2400 m of strata, whereas Mountjoy (op. cit.) measured about 914 m and Ricketts about 1200 m.

The Monster Formation is dominated by sandstone and conglomerate, interbedded with shale. Ricketts (1988) noted that there is a basal marine shale that is gradationally succeeded by coarser clastic rocks. It is probable that this basal shale is the unit mapped as KBI (Norris, 1982a) and later as KMG (Norris, 1985b), both of which were thought to be Lower Cretaceous units. Above the basal shale the succession consists of coarsening-upward and fining-upward cycles. Sandstones range from fine to coarse grained, locally pebbly, and contain abundant and varied types of cross-stratification (Ricketts, op. cit.). Conglomerate beds are most abundant at the top of the formation, and tend to form resistant cliffs. Mountjoy (1967) identified these conglomerates as a separate member, 168 m thick.

Depositional environment

Ricketts (1988) recognized that the basal Shale member was the initial marine shelf deposit of the prograding Monster succession, after a mid-Cretaceous transgression. The succeeding coarse clastic rocks were interpreted as representing progradation of coastal fans capped by alluvial deposits.

Age

Initially, the Monster Formation was given a general Late Cretaceous to Tertiary age (Green and Roddick, 1962) because of little paleontological control. Mountjoy (1967) indicated a latest Cretaceous age based on sparse paleontological information. Palynomorphs recovered from the basal Shale member indicate a Cenomanian age for these beds (Ricketts, 1988). The youngest age still remains uncertain, although the contained palynomorphs indicate a Santonian age for its upper limit (Ricketts, op. cit.).

Eagle Plain Group

Description

Interbedded sandstone and mudstone of the Eagle Plain Group (Dixon, in press a) underlie and outcrop on Eagle Plain (Fig. 6), although outcrops are not extensive. However, twenty-three wells have penetrated the succession and the thickest section (1454 m) was drilled in the Whitefish YT J-70 well. Mountjoy (1967) originally identified the succession as a formation and estimated that there was in excess of 914 m of strata. Norris (1981e, f, i, j) identified three informal map units within the formation; from the base to top Kfb, Kb, and Kcc. Unit Kfb is a sandstone-dominant unit, Kb a shale-rich succession, and Kcc consists of interbedded sandstone and shale. This last unit creates distinct stripes, visible on aerial photographs. Dixon (in press a) raised the formation to group status and identified four formations, which in ascending stratigraphic order are: Parkin, Fishing Branch, Burnthill Creek, and Cody Creek. Parkin is a newly identified shale-dominant unit; Fishing Branch, Burnthill Creek and Cody Creek correspond approximately to Norris' (op. cit.) map units.

The Parkin Formation rests unconformably on Albian strata and consists of two informal members, a basal Sandstone member, a few metres to over 200 m thick, overlain by up to 300 m of the Shale member (Fig. 39). Some shale outcrops at the base of the southwestern Eagle Plain escarpment, which had been mapped as Lower Cretaceous (Norris, 1982b), contain palynomorphs and dinoflagellates with Cenomanian affinities and belong to the Parkin Formation (D.J. McIntyre, pers. comm., 1987). Much of the strata mapped as Lower Cretaceous shale along the scarp face is probably part of the Parkin Formation, although it is known that there are also Albian shales adjacent to the escarpment. The Sandstone member has not been seen in outcrop but has been identified in numerous wells, and several cores have been cut. It varies from a "clean", very fine grained to pebbly sandstone, to argillaceous, very fine grained sandstone. The Shale member consists of medium to dark grey shale and mudstone with thin interbeds of siltstone and very fine grained sandstone. Beds of coarser clastic material tend to become more common in the upper part of the member. Millimetre-thick beds of bentonite are present in several outcrops.

Gradationally overlying the Parkin Formation is the sandstone-dominant Fishing Branch Formation (Fig. 39). The Fishing Branch Formation is up to 293 m thick and forms the sandy part of a large-scale coarsening-upward cycle that includes the Parkin Formation. There is an excellent exposure of the upper part of the Fishing Branch Formation along the Dempster Highway, where the road traverses the southwest margin of the Eagle Plain plateau (Section 84-23; Fig. 40). Core and outcrop contain very fine to medium grained sandstone and thin interbeds of mudstone. Hummocky cross-stratification and horizontal lamination are the predominant structures in the sandstones.

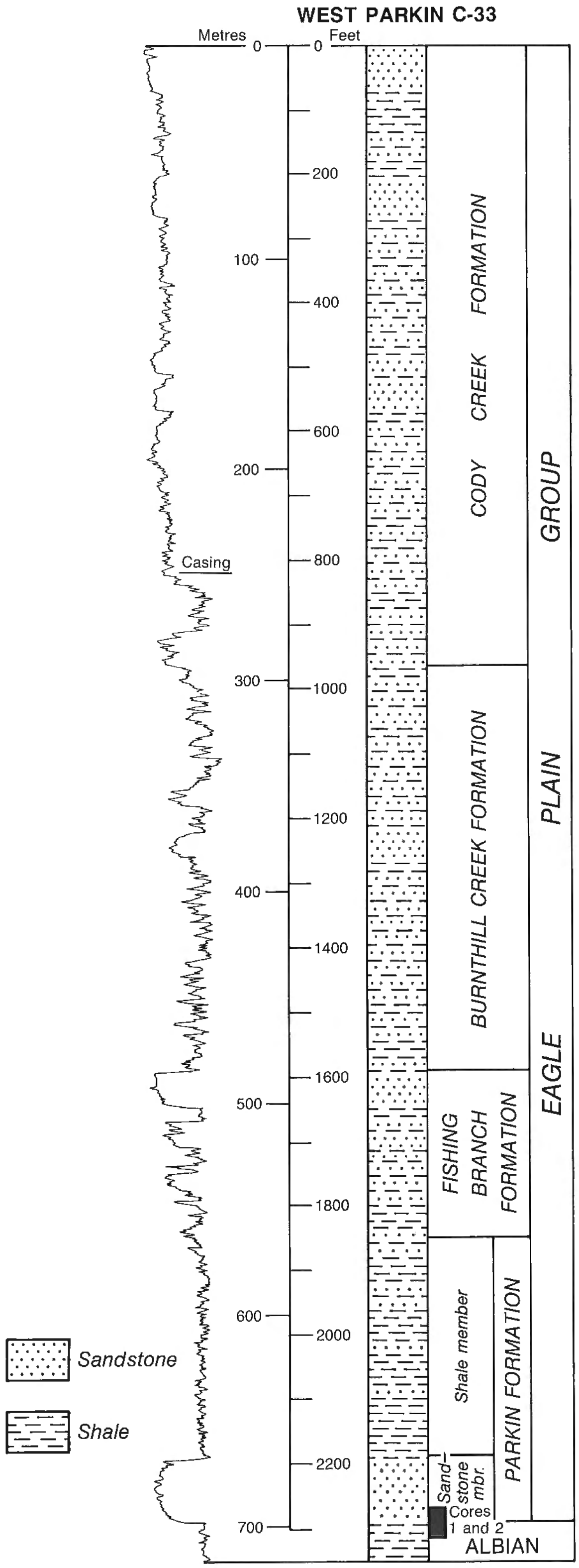

Figure 39. Gamma-ray signature and lithology log of the Eagle Plain Group in the Chevron SOBC WM West Parkin C-33 well.

The Burnthill Creek Formation is poorly exposed; it tends to weather recessively and is commonly covered by dense vegetation. In the subsurface, cores from the Ellen YT C-24, North Parkin YT D-61, and Whitestone YT N-26 wells have been cut in the unit. Core 2 from North Parkin YT D-61 intersects the boundary with the Fishing Branch Formation, which consists of a scoured surface overlain by a 4 cm thick pebbly shale. In the other cores the rocks are predominantly shale with fine laminae and thin beds of siltstone and very fine grained sandstone. Bioturbated beds are present in some units. The number and thickness of interbedded sandstones increases upsection and the Burnthill Creek Formation is gradationally overlain by Cody Creek strata.

The Cody Creek Formation is poorly to moderately well exposed and cores were cut from the unit in the Chance YT M-08 and Porcupine YT K-56 wells. Generally, the shales in this unit are poorly exposed to completely covered, whereas the sandstone intervals tend to form resistant ridges. Along the southern part of Eagle Plain the sandstones are fine to coarse grained, locally granular to pebbly, and have a distinct salt-and-pepper appearance due to the abundance of black chert grains. Carbonaceous debris is a common component of the sandstones and plant impressions have been noted. Sedimentary structures are not readily visible in the few outcrops examined, but where seen they include current-ripple lamination (some ripple-drift lamination), large-scale trough crossbedding, and low-angle planar crossbedding. Shale units in the southern Eagle Plain tend to be carbonaceous and contain small to large plant fragments. In northern Eagle Plain most sandstones are fine to medium grained and contain hummocky cross-stratification and horizontal laminae. Shale units contain numerous thin interbeds and laminae of siltstone and sandstone, in which ripple lamination is common. Bioturbated units also are present.

Depositional environment

The four formations of the Eagle Plain Group form two large-scale transgressive–regressive cycles; Parkin and Fishing Branch strata form the lower one, Burnthill Creek and Cody Creek the upper. The lower cycle appears to contain only marine beds and the sandstones of the Fishing Branch Formation are dominated by shelf storm-deposits. The upper cycle also is predominantly marine, although some of the Cody Creek beds in the southern part of Eagle Plain contain fluvial channel and overbank deposits (Dixon, in press a).

Age

Mountjoy (1967) reported the identification of some plant fossils and bivalves that indicated a possible Cenomanian age, but which could range into the Late Albian. Palynomorphs and dinoflagellates from the Parkin Formation indicate a Cenomanian age for some of these strata (D.J. McIntyre, pers. comm., 1986, 1987). The youngest age is not known with any degree of certainty, although some of the plant forms may indicate an age as young as Santonian. Along Porcupine River there are numerous outcrops of Upper Cretaceous strata that are probably correlative with the Eagle Plain Group, and it has been indicated that some of the strata are as young as Campanian or Santonian (Norris, 1981e).

Upper Cretaceous on Porcupine River, Old Crow Basin

Description

On the banks of Porcupine River, between Old Crow and its junction with Driftwood River, there are extensive exposures of Upper Cretaceous strata in the cut banks (Norris, 1981e). However, most of the cliffs are in horizontal or low dipping strata; consequently, they do not represent much vertical section. At the eastern exposures (those near Driftwood River), interbedded shale and thin sandstone beds are common. From the junction with Lord Creek to Old Crow, the strata are predominantly sandstone. The majority of the sandstones are thoroughly bioturbated and many have a distinct green or ochre tint, apparently due to the clay content. Some rippled and crossbedded sandstones were noted, but are not common. These latter beds are less argillaceous than the bioturbated sandstones and commonly display a salt-and-pepper appearance due to the presence of black chert. This characteristic is similar to that of the Cody Creek sandstones of the Eagle Plain Group.

Depositional environment

The ubiquitous bioturbation in Upper Cretaceous strata along Porcupine River and the presence of some dinoflagellates attest to its marine character. The ages assigned to these strata indicate an equivalence with the

Figure 40. *Outcrop of the Fishing Branch Formation, Eagle Plain Group, along the Dempster Highway, on the southwest scarp of Eagle Plain (Section 84-23). Sandstone beds consist of amalgamated, hummocky cross-stratified units and are separated by thin shale beds. ISPG photo. 2584-2.*

Eagle Plain Group; consequently, they would represent a more seaward depositional setting than the Eagle Plain strata, probably an inner to mid shelf environment.

Age

The only published age determinations are those on Norris' (1981e) map, which indicate a maximum age range for the fossils of Cenomanian to Campanian but which could be as short a range as Turonian to Santonian. Dinoflagellates identified from Section 85-10 (Fig. 2) (D.J. McIntyre, pers. comm., 1986) indicate a probable Turonian age, similar to that identified on Norris' map. At Section 85-6 (Fig. 2) a few dinoflagellates of possible Cenomanian or Turonian age were identified (D.J. McIntyre, pers. comm., 1986), in contrast to the Santonian age indicated on Norris' map.

Bonnet Plume Formation

Description

The Bonnet Plume Formation was named by Mountjoy (1967) for a succession of weakly consolidated clastic sediments located in the Bonnet Plume Basin, situated between the Wernecke Mountains and the southern end of the Richardson Mountains (Fig. 1). Mountjoy (op. cit.) indicated that there were about 1500 m of strata, but Norris and Hopkins (1977) suggested that the structural configurations in the basin could only accommodate a few hundred metres of Bonnet Plume strata. Bonnet Plume strata rest unconformably on Paleozoic rocks and are overlain by a thin Quaternary cover.

Medium to coarse grained sandstone is the dominant lithology with subordinate amounts of conglomerate, siltstone, shale, and lignite. Norris and Hopkins (op. cit.) divided the succession into two informal members, a Lower member and an Upper member. The Lower member is predominantly conglomerate and the Upper member consists of interbedded sandstone, shale and lignite.

Depositional environment

Norris and Hopkins (1977) concluded that the Bonnet Plume Formation is an alluvial deposit and Long (1981) re-emphasized this interpretation with an account of the various depositional facies encountered in intermontane fluvial basins, using the Bonnet Plume Basin as one example.

Age

In Mountjoy's (1967) original description he indicated that the recovered pollen and spores suggested a Campanian or Paleocene age for the formation. Rouse and Srivastava (1972) and Norris and Hopkins (1977) identified the Lower member as Middle to Late Albian, and the Upper member as Maastrichtian to Paleocene. Unpublished palynological studies by A.R. Sweet (Geological Survey of Canada, pers. comm., 1987) have shown that the Bonnet Plume Formation is Late Cretaceous for the most part and may be as young as Late Paleocene, or even Eocene, and that Middle/Late Albian strata may be present in the lowest part of the formation.

Boundary Creek Formation

Description

The Boundary Creek Formation was named by Young (1975a) for Upper Cretaceous shales that outcrop in the northernmost Richardson Mountains and along parts of the Yukon coastal plain. It is equivalent to Jeletzky's (1960) informally named Upper Cretaceous shale division, from the "Treeless Creek" area on the eastern flanks of the Richardson Mountains (Section 82-10; Fig. 2). Isolated exposures are present to the west of Fort McPherson (Norris, 1981g), in close proximity to the Dempster Highway. The formation is about 250 m thick in its type area, up to 305 m at "Treeless Creek", and as much as 1100 m near Cuesta Creek (Young, op. cit.). However, the last section may include fault-repeated strata. Furthermore, large-scale, synsedimentary recumbent folds have been seen at Boundary Creek, which, if not noted during measurement of a section, could give an anomalously thick succession. Only a thin erosional remnant can be traced eastward to the southern end of Tuktoyaktuk Peninsula.

The Boundary Creek Formation rests abruptly on Albian strata at its type area (Fig. 41), and is erosionally overlain by coarse clastic rocks of the Cuesta Creek Member, Tent Island Formation. The lower contact is an important tectono-stratigraphic boundary in northern Yukon, separating dense, highly compacted, brittlely fractured strata below from less dense, less compacted, plastically deformed strata above.

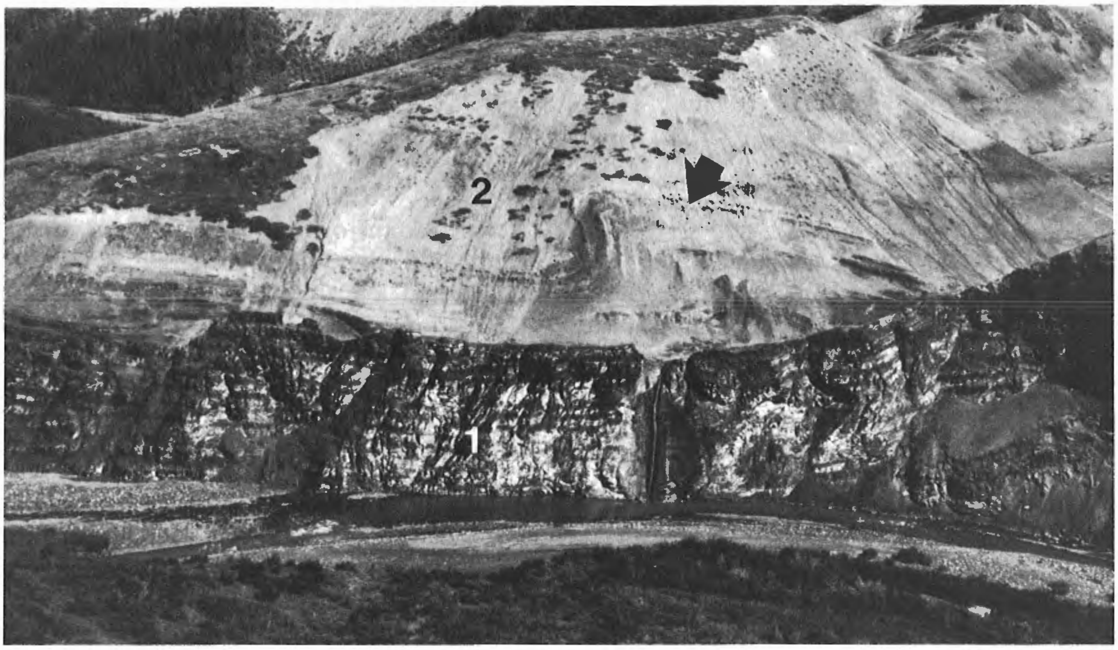

Figure 41. The Boundary Creek Formation (2) abruptly overlying the Albian Rapid Creek Formation (1) at Fish River (near Section 84-8). Note the detached fold in Boundary Creek shales (arrow). The photograph was taken a few kilometres southeast of the type area of the Boundary Creek Formation. ISPG photo. 2236-7.

Soft, fissile shale is the dominant lithology. Usually it is light grey to black, but surface oxidation produces local patches of yellow and orange. Centimetre thick beds of white to yellow weathering bentonite occur throughout the formation. Brownish red weathering ironstone concretions are very common and usually occur in distinct zones throughout the succession. Surface oxidation of pyrite leads to the precipitation of selenite and abundant crystals are present on the outcrops. Jeletzky (1960) divided the Boundary Creek Formation at "Treeless Creek" into three informal members, based on the weathering colour. Organic carbon content of Boundary Creek strata is high, averaging between 2 and 4 per cent but may be as high as 7 per cent (unpublished analyses from field samples).

Depositional environment

Scarce marine macrofossils (Jeletzky, 1960) and abundant marine dinoflagellates (D.J. McIntyre, *in* Dixon et al., 1985) attest to the marine origin of the Boundary Creek Formation. The high organic content suggests high primary productivity or deposition in a low-oxygen environment. Its equivalence to the shelf and nearshore sediments of the Parkin and Fishing Branch formations of Eagle Plain suggests that the Boundary Creek shales were deposited in an outer shelf to slope environment.

Age

The Boundary Creek Formation generally has a sparse macrofauna, although the bivalves and ammonites identified (Jeletzky, 1960) indicate a late Cenomanian to Turonian age. Palynomorphs and dinoflagellates, on the other hand, are abundant and these also indicate a Cenomanian to Turonian age (D.J. McIntyre, *in* Dixon et al., 1985). Young (1975a) correlated Boundary Creek strata with the Santonian to Campanian Smoking Hills Formation, thereby implying that the Boundary Creek extended into the Campanian. Although the two formations contain similar palynomorphs and dinoflagellates there are sufficient differences to warrant separation of the two units. Also, physical correlations indicate the presence of a major unconformity between the two formations (figure 28B in Dixon et al., 1985).

Smoking Hills Formation

Description

The Smoking Hills Formation (Yorath et al., 1975) was originally referred to as the bituminous shale zone and its principal area of outcrop is on Horton River, 300 km east of the Mackenzie Delta (Fig. 42). It can be identified in wells on Tuktoyaktuk Peninsula and parts of the south Mackenzie Delta (Myhr, 1975; Dixon et al., 1985; Dixon et al., in press) (Fig. 6). Its westernmost outcrops are at the southern end of the Caribou Hills, on the east side of Mackenzie Delta. These outcrops and others between Caribou Hills and Sitidgi Lake were mapped by Norris (1981d) and identified by Price et al. (1980) as Tent Island strata; however, palynological studies by D.J. McIntyre (unpublished data) indicate that the strata are Campanian–Santonian in age, and therefore correlative with the Smoking Hills Formation. Lithologically, the strata at these locations are more like Smoking Hills shales than Tent Island shales.

The Smoking Hills Formation is up to 130 m thick in outcrop and several hundred metres thick in the subsurface. On Horton River it rests abruptly on Albian strata; in the subsurface it rests unconformably on Paleozoic to Turonian strata.

The formation consists of dark grey to black, fissile shale interbedded with bentonite beds that are a few centimetres to one metre thick. Ironstone concretions and cone-in-cone limestone bands are common. Organic carbon content is high; samples with up to 12 per cent organic carbon have been identified. Pyrite is a common component and its oxidation at the surface causes the organic carbon to ignite and burn (Matthews and Bustin, 1984). In the subsurface the Smoking Hills Formation has a very distinct gamma-ray signature, with a prominent basal radioactive zone overlain by "normal" shales in which other, thinner, radioactive shale zones are interbedded (Fig. 43).

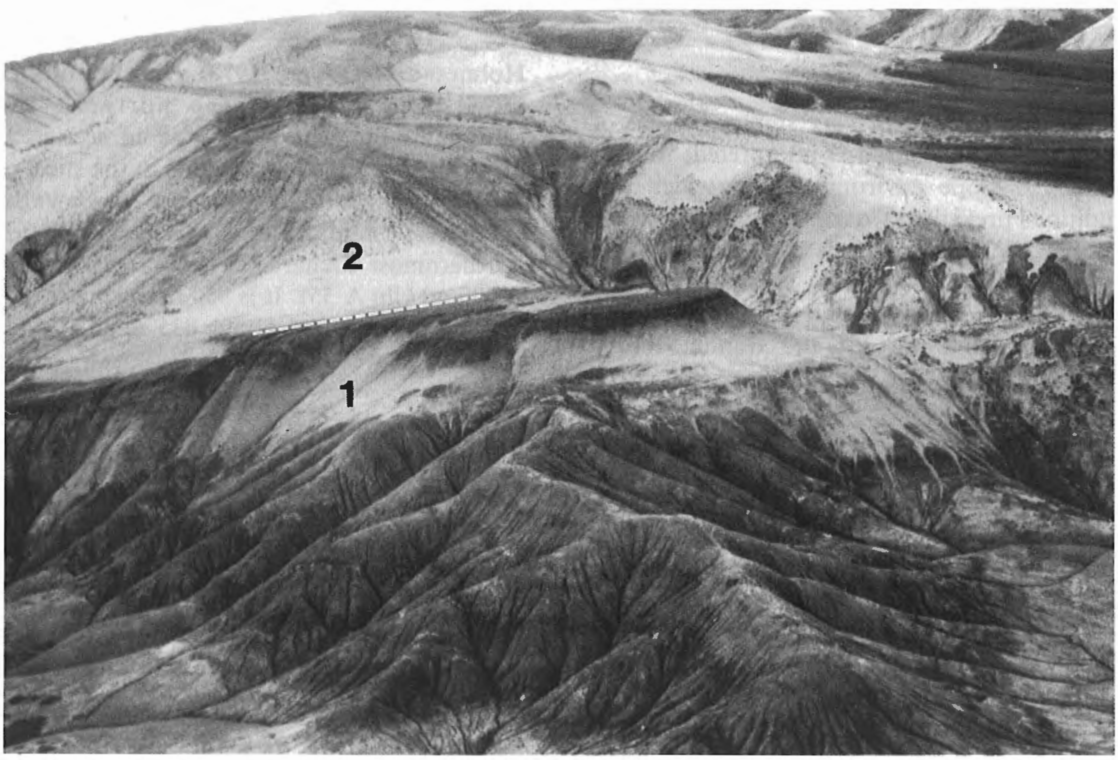

Figure 42. The Smoking Hills Formation (1), abruptly overlain by light-grey shale of the Mason River Formation (2) on the south slope of Horton River valley. ISPG photo. 2236-3.

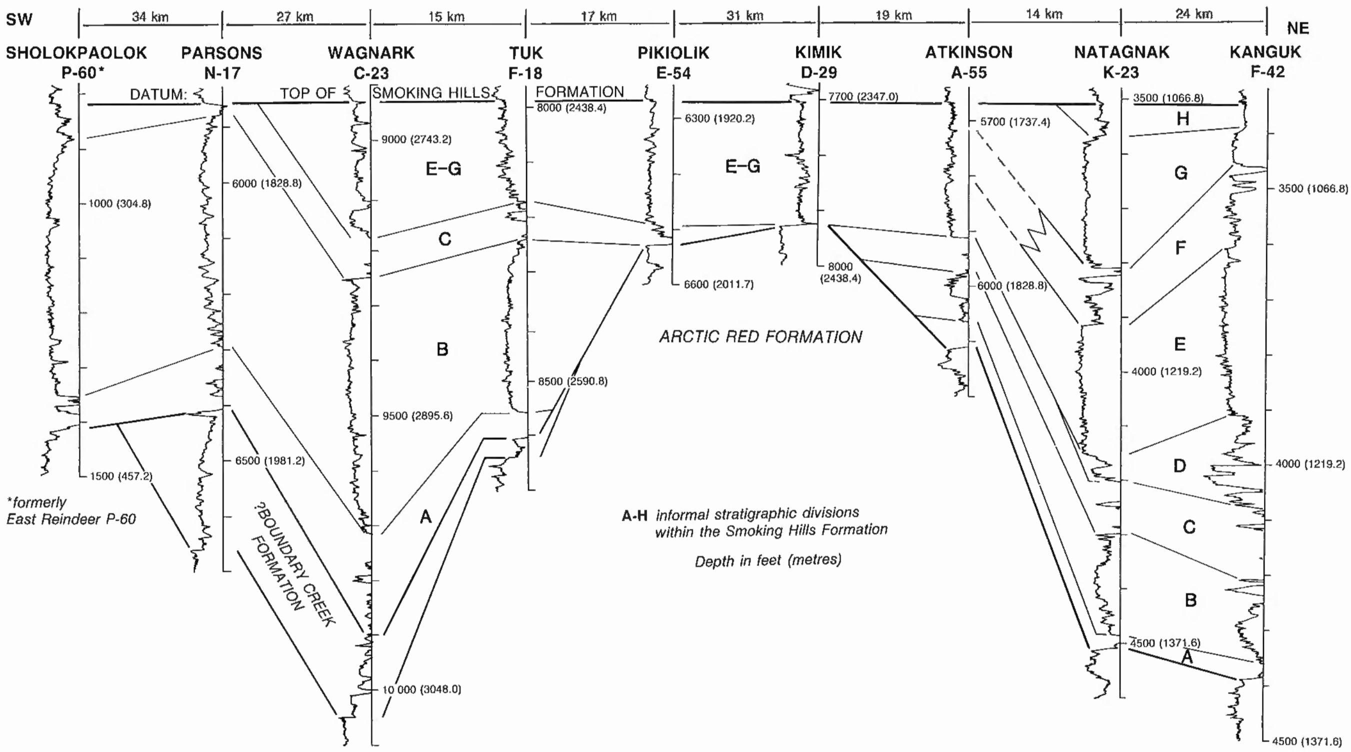

Figure 43. Correlation diagram for the Smoking Hills Formation under Tuktoyaktuk Peninsula, based on gamma-ray logs. Depths are given in feet.

Depositional environment

A depositional environment very similar to that of the Boundary Creek Formation is interpreted; that is, an outer shelf to slope environment, in which low oxygen conditions prevailed. Coarse clastic, nonmarine and nearshore, lateral equivalents include the Little Bear Formation in the Norman Wells area, and possibly may include the Burnthill Creek and Cody Creek formations, and part of the Bonnet Plume Formation.

Age

McIntyre (1974) identified Santonian to Campanian palynomorphs and dinoflagellates in the Smoking Hills Formation, and Yorath et al. (1975) suggested that it may be as old as Coniacian. However, the Coniacian age is speculative, no age-diagnostic Coniacian fossils have been identified.

Tent Island Formation

Description

Young (1975a) defined the Tent Island Formation, prior to which it had been referred to by a variety of informal names (Young, 1971; Chamney, 1972; Holmes and Oliver, 1973). It outcrops extensively along Fish River in the northern Richardson Mountains (its type area), and in scattered locations along the Yukon coastal plain. In the subsurface it has been penetrated in only a few wells on the southwestern margin of the Mackenzie Delta and northernmost Richardson Mountains (e.g., Fish River B-60 and Ulu A-35). It is 950 m thick at its type section (Young, 1975a) and about 835 m in the nearby Fish River B-60 well.

Two members are recognized in the Tent Island Formation's known area of occurrence, a basal sandstone-conglomerate unit, the Cuesta Creek Member, and an overlying Mudstone member (Young, 1975a). The Cuesta Creek Member is about 100 to 130 m thick on Fish River (Section 87-5; Fig. 2); elsewhere, thicknesses range from 40 to 110 m. At the type area there are four distinct intervals, in ascending order these are: 1) interbedded sandstone and shale, 2) interbedded sandstone and conglomerate, 3) mudstone, and 4) interbedded sandstone and conglomerate (Young, 1975a). Lateral facies changes preclude the presence of the same vertical succession at other localities. The beds below the top unit contain several sets of beds with low-angle foreset dips (Fig. 44). A large-scale scour separates the uppermost interval from underlying beds (Fig. 44).

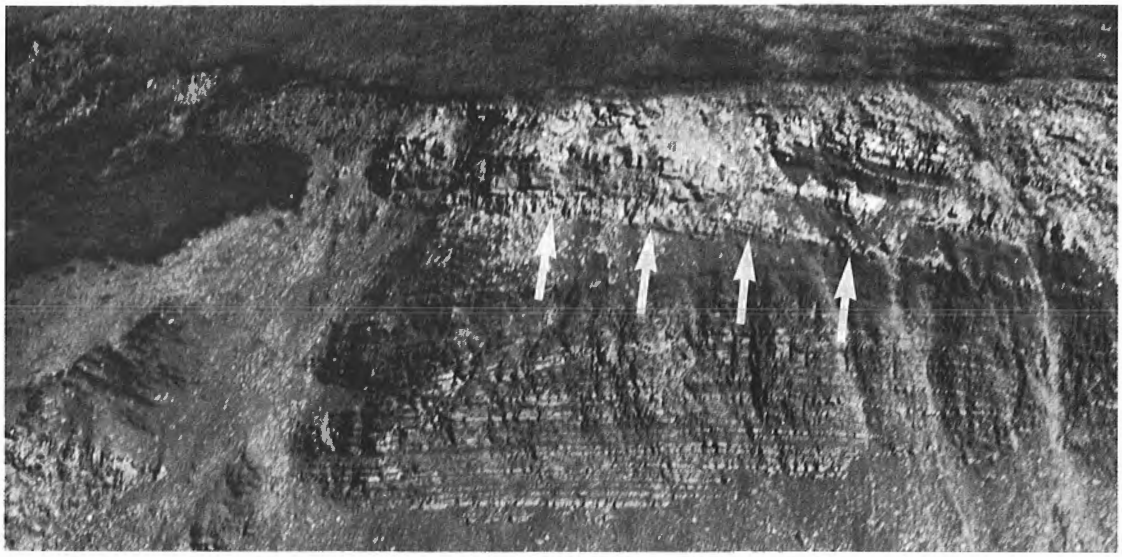

Figure 44. The Cuesta Creek Member of the Tent Island Formation at Fish River (Section 87-12). Note the scour surface (arrows) and the large-scale, low-angle, foreset-like bedding below it. ISPG photo. 2846-23.

Clasts in the conglomerates range up to 1 m; however, most are a few centimetres in diameter. Chert and sandstone pebbles are the dominant clast types. Most of the conglomerates are massive, usually have erosional bases, generally are no thicker than a few metres, and many are only a few tens of centimetres thick. Sandstone beds also are commonly massive, a few centimetres to about 1 m thick. Horizontal lamination and rare cross-stratification have been noted in some sandstone beds. More common, but not abundant, are sole marks, especially in thin bedded sandstones interbedded with mudstones.

The bulk of the Tent Island Formation consists of the Mudstone member, which comprises medium to dark grey, soft mudstone with thin interbeds of siltstone and very fine grained sandstone. Horizontal and ripple laminae are common in the coarser clastic beds. Pebbly mudstones are present locally near the contact with the Cuesta Creek Member.

Depositional environment

Holmes and Oliver (1973) and Young (1975a) concluded that the Cuesta Creek Member is a predominantly fluvial deposit and the Mudstone member a marine shelf deposit. Dixon (1986b, 1988), however, suggested that the facies were more consistent with deposition as sediment gravity-flow deposits, either in a submarine canyon or inner submarine fan. This interpretation was later supported by Myers (1990). The Mudstone member is a marine deposit formed as progradation proceeded oceanward over the submarine fan deposits. As such, the lower beds were probably deposited on the continental slope (this is supported by the presence of pebbly mudstones of debris-flow origin in the lowermost part of the member) and the upper beds on the outer to middle shelf.

Age

Originally the age of the Tent Island Formation was considered to extend from the Campanian into the Maastrichtian, and possibly be as old as Santonian (Young, 1975a, p. 10, 11). Also, it was suggested that the age of the Cuesta Creek Member was not everywhere the same (Young, op. cit.). However, these conclusions were based on what appears to be inconclusive foraminiferal data. Sweet (1978) re-examined the palynomorphs and concluded that the entire Tent Island Formation is Maastrichtian, possibly only late Maastrichtian.

Moose Channel Formation

Description

Mountjoy (1967) established the Moose Channel Formation for a sandstone-dominant succession above Tent Island Formation mudstones at Fish River in the northern Richardson Mountains (Section MC; Fig. 2). The original description included coal-bearing strata at

Aklak Creek, a few kilometres to the west of Fish River. Young (1975a) recognized these coal-bearing strata as a younger succession, separated from Moose Channel sandstones by a shale interval. He named this shale unit the Ministicoog Member of the Moose Channel Formation but left the lower sandstone-dominant part of the formation unnamed. Moose Channel strata are present in isolated outrops on the Yukon coastal plain and are known from the subsurface in a few wells in the vicinity of Shallow Bay. Strata identified as Moose Channel Formation in some wells by Young (1975a) and Young et al. (1976) are now believed to be younger strata, part of the lower Reindeer Formation (e.g., in the Ellice O-14 and Unipkat I-22 wells; Dixon et al., 1985, in press). At the type section, the formation is about 900 m thick and in the nearby Fish River B-60 well it is 1044 m thick.

The bulk of the lower, unnamed, part of the formation in the type area is sandstone, with subordinate amounts of interbedded mudstone (Fig. 45). Grain size is predominantly fine to medium sand, but local coarse grained to pebbly beds are present, especially in the lowermost part. Northwest of the type area, Young (1975a) reported the presence of some coal in Moose Channel strata. Fining-upward and coarsening-upward cycles have been identified in parts of the formation (Young, op. cit.). Sedimentary structures are numerous and diverse, including planar cross-stratification, ripple and horizontal lamination and, locally, some hummocky cross-stratification. Scour surfaces at the base of fining-upward cycles suggest channel-fill deposits. Marine trace fossils occur in some strata (Young, op. cit.).

The Ministicoog Member consists predominantly of light grey mudstone with thin interbeds of siltstone and very fine grained sandstone. Locally, the sandstone interbeds comprise a significant portion of the succession (Young, 1975a). In the type section on Fish River, there are at least three sandstone-rich intervals, all less than 30 m thick (Young, op. cit.). The thin siltstone and sandstone beds invariably are plane or ripple laminated. Where sandstone is more abundant in the Ministicoog Member, individual beds are thicker, generally coarser grained, and contain larger scale cross-stratification than the thinly bedded sandstones. In the type section, Young (op. cit.) reported 366 m of strata but, in the nearby Fish River B-60 well, apparently there are only 177 m, and 140 m in Ulu A-35. These three localities are not too distant from each other; consequently, the discrepancy in

Figure 45. The Moose Channel Formation at Fish River (Locality MC on Figure 1). Note the massive channel-sandstone at the top of the cliff (arrow). ISPG photo. 2584-1.

thicknesses between the well and outcrop data is problematic. The similarity of thicknesses in the wells suggests the possibility of some error in the measurement of the outcrop.

Depositional environment

Young (1975a) identified three depositional facies in the lower, sandy part of the Moose Channel Formation: alluvial, deltaic, and littoral. Marine foraminifers and the general lithology in the Ministicoog Member attest to its marine shelf character; however, local depositional variations have been noted by Young (1975a) who identified tidal deposits in some of the sandier sections.

Age

The Ministicoog Member contains microfossils of the *Reticulophragmium borealis* Zone, thus indicating a Paleocene age (McNeil, 1989, and *in* Dixon et al., 1985). This age assignment is much younger than that originally proposed by Young (1975a). The late Maastrichtian age of the Tent Island Formation and the Paleocene age of the Ministicoog Member limit the age of the lower part of the Moose Channel Formation to latest Maastrichtian and Paleocene.

Reindeer Formation

Description

Mountjoy (1967) named the poorly consolidated sandstones and conglomerates in the Caribou Hills, on the east side of Mackenzie Delta, the Reindeer Formation (Fig. 46). At the northern end of Richardson Mountains, Young (1975a) identified and named the Aklak Member in the formation. Changes from the original usage were documented by Price et al. (1980), who recognized a major unconformity within the Caribou Hills section, as did earlier workers (Doerenkamp et al., 1976). Price et al. (1980) redefined the Reindeer Formation as a succession of interbedded sandstone, conglomerate and mudstone that lies between the Ministicoog Member of the Moose Channel Formation and an Eocene shale unit present only in the subsurface (an informal unit of Young et al., 1976, that was later formally named the Richards Formation by Young and McNeil, 1984). At the base of the Caribou Hills section, Price et al. (op. cit.) recognized a very thin equivalent of the Moose Channel Formation, and more specifically the Ministicoog Member. Young et al. (1976) had suggested similar changes to the stratigraphy but on a less formal basis. Because of the nomenclature problems and the lack of a complete Reindeer Formation in outcrop, Young and McNeil (1984) designated the Kumak J-06 well, between depths 1143

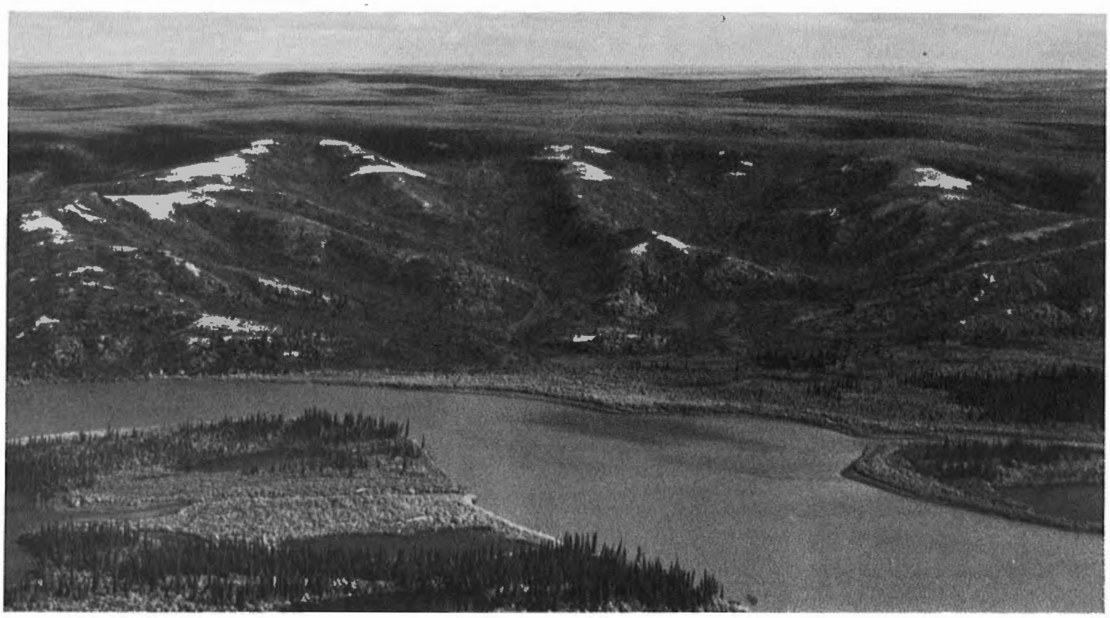

Figure 46. The Reindeer Formation at Caribou Hills. (Photograph courtesy of D.J. McIntyre.) ISPG photo. 2481-1.

and 2499.4 m (3750 and 8200 ft), as a reference section for the Reindeer Formation. They assumed that the shale below 2499.4 m was the Ministicoog Member of the Moose Channel Formation. However, recent work on the foraminiferal assemblages indicate that the shale is an intra-Reindeer shale, younger than the Ministicoog shale (D.H. McNeil, *in* Dixon et al., 1985, in press). Consequently, there is no designated complete section of the Reindeer Formation, *sensu* Price et al. (op. cit.). To date there is no known well in the Mackenzie Delta area that penetrates a complete section of the Reindeer Formation. To further complicate the stratigraphy, an intra-Reindeer unconformity, manifested as a major erosional surface, has been recognized in the west Beaufort Sea in the Natsek E-56 well (Dixon et al., 1985; Dietrich et al., 1989). The lower and upper parts of the Reindeer succession were named the Aklak and Taglu "sequences" respectively by Dietrich et al. (op. cit.). Under Mackenzie Delta, the Reindeer succession appears to be conformable, but it is believed that the base of the "Ellice shale" is approximately equivalent to the western unconformity (Dixon et al., 1985). For the purposes of the following discussion the Reindeer Formation *sensu* Price et al. (op. cit.) will be used.

In the Caribou Hills the Reindeer Formation consists of interbedded sandstone, pebbly sandstone, conglomerate, mudstone, and some lignite beds (Fig. 46). The strata are weakly cemented to unconsolidated, in contrast to the lithified strata in the northern Richardson Mountains and in the subsurface under Richards Island. In the northern Richardson Mountains, strata of the lower Reindeer Formation are poorly exposed in stream valleys, where they consist of fining-upward cycles, commonly incorporating coal beds within the upper part of each cycle (Fig. 47) (Young, 1975a). These coal-bearing strata were named the Aklak Member by Young (op. cit.). Under Mackenzie Delta, large-scale coarsening-upward cycles laterally replace the fining-upward cycles and coal becomes less common (Young et al., 1976; Dixon, 1981; Nentwich and Yole, 1982). Bentonite beds are present throughout the Reindeer Formation, but are not laterally persistent. Also, the lower Reindeer succession contains more thick shale intervals than the upper part.

In the Natsek E-56 well (Fig. 48) in the west Beaufort Sea, the lower Reindeer consists of interbedded sandstone, conglomerate, mudstone and

Figure 47. The Reindeer Formation at Aklak Creek in the northern Richardson Mountains. (Photograph courtesy of D.J. McIntyre.) ISPG photo. 2428-2.

coal, arranged in fining-upward cycles and small-scale coarsening-upward cycles (Dietrich et al., 1989). Equivalent strata to the upper Reindeer consist of mudstone, siltstone, and thin sandstone interbeds (Dietrich et al., 1989).

Depositional environment

The lower Reindeer Formation contains typical fluvial channel, floodplain and crevasse splay deposits in outcrop areas (Aklak Creek and Caribou Hills), as well as in the western Beaufort Sea. These deposits are arranged in fining-upward and small-scale coarsening-upward cycles. They occur over a large area and grade laterally into coarsening-upward, delta-front cycles under Mackenzie Delta. Sediments of a large delta-complex were deposited over much of the Yukon coastal plain and under part of the inner shelf of the present western Beaufort Sea. During deposition of the upper Reindeer Formation, deltaic deposition switched to the east and the locus of deltaic sedimentation was situated over Mackenzie Bay/Richards Island. In the western Beaufort Sea, prodelta/shelf conditions prevailed.

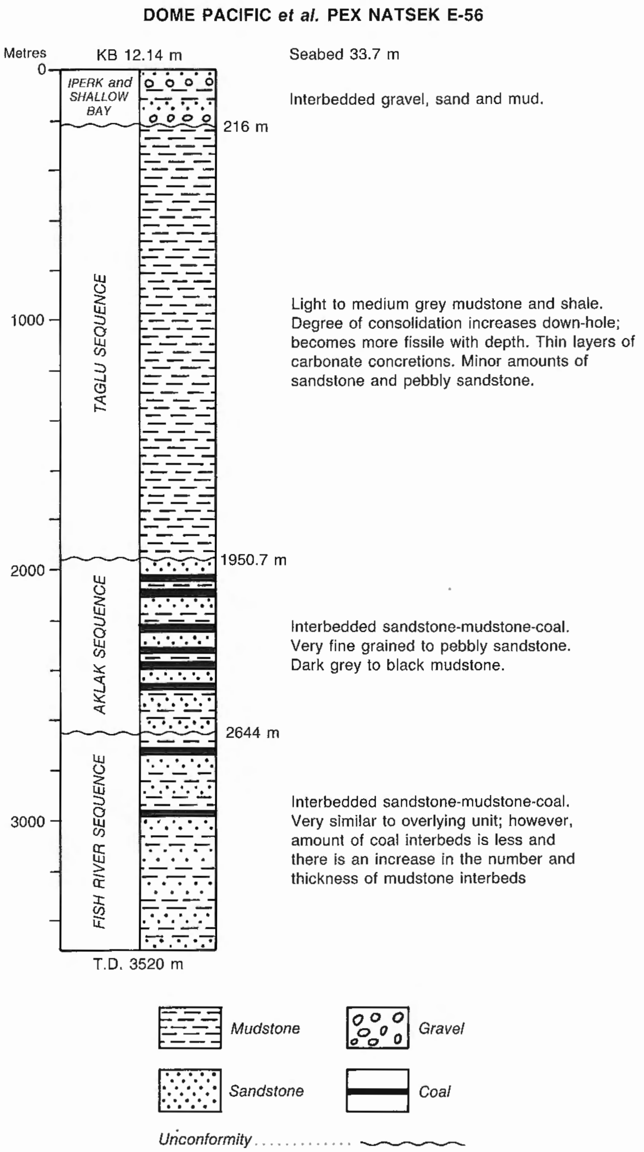

Figure 48. Lithological log of the succession in the Natsek E-56 well. The sequence terminology is from Dietrich et al. (1989). The Reindeer Formation is approximately equivalent to the Aklak and Taglu sequences.

Age

The lower Reindeer Formation contains foraminifers of the *Portatrochamina* sp. 2849, and possibly the upper part of the *Reticulophragmium borealis*, interval zones (McNeil, 1989), associated with a distinctive microfloral assemblage (McIntyre, *in* Dixon et al., 1985). A Paleocene to Early Eocene age is indicated by the fossils. The upper Reindeer Formation contains foraminifers of the *Portatrochamina* sp. 2850 Interval Zone and a distinctive microfloral assemblage (McIntyre, *in* Dixon et al., 1985) of Early to Middle Eocene age. The fossils in the Reindeer Formation indicate an age range from the Late Paleocene to Early or Middle Eocene. The vertical faunal and floral changes do not coincide exactly with the intra-Reindeer unconformity—there is some overlap of the assemblages across the unconformity. However, the distinctiveness of the fossils between the lower and upper parts of the Reindeer Formation can be used to judge the approximate position of the unconformity, or surface of transgression, in a succession of Reindeer strata.

Richards Formation

Description

Bowerman and Coffman (1975), using subsurface data, noted the presence of a thick prodelta shale interval overlying a sandstone-dominant succession (Reindeer Formation) but did not name the shale. Young et al. (1976) informally named the shale, "the unnamed Eocene shale", and Young and McNeil (1984) formally named it the Richards Formation. It is present only in the subsurface and has been penetrated by exploration boreholes under Richards Island, where it attains a known thickness of about 2300 m.

Generally it rests abruptly on Reindeer strata, although a thin zone of silty-sandy mudstones may occur between Reindeer sandstones and Richards shales. In contrast, Young and McNeil (op. cit., p. 20) considered the contact to be "most commonly transitional in character."

The bulk of the Richards Formation consists of silty to sandy shale with some thin units of muddy sandstone and pebbly mudstone. Bentonite beds are present but not common. Under Richards Island the lowermost 60 to 200 m of the Richards Formation form a distinct, generally sandstone-free interval that has a much lower interval velocity than the overlying shale (Fig. 49). This basal interval usually is abruptly overlain by silty to sandy mudstone beds.

In its type area (i.e., the Taglu gas field), the Richards Formation is abruptly overlain by Kugmallit sandstone, whereas in the Ivik area (northeast of Taglu) this contact is gradational, and is generally manifest as a coarsening-upward cycle (Fig. 50). Young and McNeil (op. cit.) also noted that Richards strata are truncated in the Kilagmiotak wells (F-48 and M-16). The geographic change in character of the boundary between the Richards and Kugmallit formations is a function of the lithostratigraphic definitions employed. It is now recognized that a major unconformity does exist where Kugmallit strata rest abruptly on Richards shale, such as in the Taglu area, but that in the Ivik area the unconformity occurs within the interval of interbedded sandstone–shale that lithostratigraphically is part of the lower Kugmallit Formation (Fig. 50).

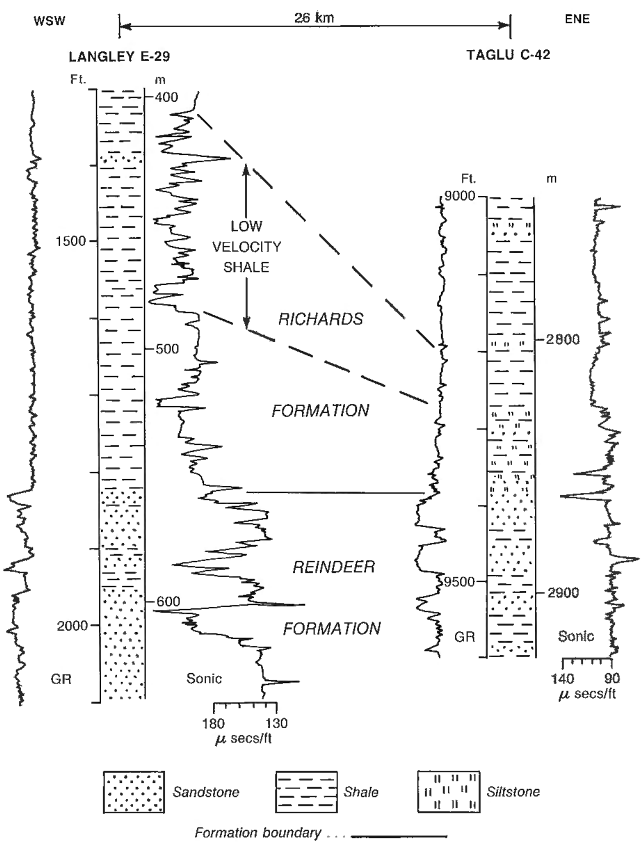

Figure 49. Well logs for the strata adjacent to the contact between the Reindeer and Richards formations in the Taglu C-42 and Langley E-29 wells, including the basal low-velocity interval in the Richards Formation. Sonic/gamma-ray logs.

Depositional environment

The bulk of the Richards Formation is interpreted as having been deposited in a prodelta/shelf environment. Cores of matrix-supported conglomerate from the Taglu G-33 and Adgo C-15 wells are from typical debris-flow deposits (Glaister and Hopkins, 1974) that were probably deposited on the distal delta-front or slope. The fact that some of the delta-front cycles of the lower Kugmallit Formation in the Ivik area occur below a major unconformity indicates that they are part of the same depositional sequence that forms the bulk of the Richards Formation (i.e., genetically part of the same prograding succession), and that a major delta was forming during Richards deposition, although most of the deltaic strata were subsequently eroded.

Age

The lower Richards Formation is rich in a diverse assemblage of pollens and spores as well as numerous species of the dinoflagellate *Wetzeliella* (Staplin, 1976; McIntyre, *in* Dixon et al., 1985). Richards strata also contain foraminifers of the *Haplophragmoides* sp. 2000 Interval Zone (McNeil, 1989). The diatom *Stellarima* Zone which occurs widely in the lower part of the Richards Formation, is of Middle Eocene age (McNeil, 1990). The fauna and flora indicate that the Richards Formation is Middle Eocene to possibly Late Eocene in age.

Kugmallit Formation

Description

A thick, sandstone-dominant succession overlying the Richards Formation was originally referred to as the "upper Paleogene clastic unit" (Young et al., 1976), and was later formally named the Kugmallit Formation (Young and McNeil, 1984). Within the Canadian petroleum industry this interval also has been informally referred to as the "Pullen Sands" or "Pullen Delta" (e.g., Willumsen and Coté, 1984). Young and McNeil (op. cit.) have the Beaufort Formation unconformably overlying Kugmallit strata, even though lithologically the two units are similar. The reason for creating two divisions in this lithologically similar succession appears to be based on Staplin's (1976) interpretation of an unconformity between the two units in the Taglu G-33 well. A significant reduction and change in the flora occurs across this surface. This biostratigraphic change coincides with a change from interbedded sandstone and mudstone upward into a predominantly sandstone and conglomerate sequence, which is here interpreted as a change from middle delta-plain deposits to upper delta-plain sediments, the latter dominated by thick, channel deposits. Log correlations and reflection seismic data do not indicate a major unconformity at the level suggested by Staplin (1976), and reiterated by Young and McNeil (1984) (Fig. 51). However, in the Taglu area, foraminifers indicative of a correlation with the shale-dominant Mackenzie Bay Formation do occur in Young and McNeil's Beaufort Formation, but at a higher stratigraphic level than their basal unconformity. Basinward of the Taglu wells, Mackenzie Bay strata rest directly on Kugmallit sandstones. Consequently, it would appear that basin-margin, coarse clastic equivalents of the shale-dominant Mackenzie Bay Formation occur within Young and McNeil's Beaufort Formation. However, their choice of stratigraphic level for the basal unconformity of the Beaufort Formation remains suspect. Dixon et al. (in press) avoided the lithostratigraphic terminology problems caused by these lateral facies changes by using a sequence analysis approach to the stratigraphy, and included the coarse clastic strata (Beaufort Formation) in the Mackenzie Bay Sequence. Also, recent work on the type area of the Beaufort Formation (Prince Patrick Island) shows that it is a Pliocene unit (Fyles, pers. comm., 1990); therefore, the Miocene unit identified by Young and McNeil (op. cit.) as Beaufort Formation under the Mackenzie Delta is misnamed.

Young and McNeil (op. cit.) noted that the "white-clay unit" in the Caribou Hills section (Fig. 52) (Price et al., 1980) could be equivalent to the Kugmallit Formation. There is a marked age difference between the clay unit and the underlying Reindeer Formation—Oligocene versus Paleocene to early Eocene—which suggested the presence of a major

Figure 52. The "white-clay unit" of the Kugmallit Formation (2), underlain by Reindeer Formation gravels (1) in the Caribou Hills (Locality CH on Figure 1). ISPG photo. 2428-3.

unconformity to Price et al. (op. cit.). The palynomorphs recovered from the white-clay unit show many affinities to those recovered from the Kugmallit Formation, and the correlation of the two seems a reasonable assumption. Furthermore, the gravels and sands overlying the white-clay unit in the Caribou Hills probably are part of the same nonmarine succession. These gravels and sands are in structural continuity with the white clay. There are no regional indications to suggest that they rest unconformably on the white clay, and, on a regional basis, the correlations outlined above make some sense of these isolated gravels and sands. One of the reasons why these Caribou Hills gravels were placed in the Beaufort Formation (Young, 1978, p. 55-57) was the comparison of their flora with that of the Miocene Beaufort Formation of Banks Island (Doerenkamp et al., 1976). However, the reported flora contains long-ranging forms that are not age-diagnostic of the Miocene (D.J. McIntyre, pers. comm., 1987). To add further confusion, Norris (1981d) mapped the overlying Storm Hills gravels as Beaufort Formation, although these are most probably Plio-Pleistocene strata of the Iperk–Nuktak unit. As indicated above, the Beaufort Formation in its type area is now believed to be Pliocene in age. The Caribou Hills gravels, therefore, are unlikely to be Beaufort Formation equivalents.

In Caribou Hills, the strata herein assigned to the Kugmallit Formation are about 500 m thick. Strata thicken rapidly offshore and are estimated to be upward of 4000 m thick in the Issungnak–Isserk area, where the depocentre is located. Thicknesses in the west Beaufort area are not known with any degree of accuracy, although seismic correlations indicate substantial thinning to the west.

Young and McNeil (1984) subdivided the Kugmallit Formation into two members, a lower, Ivik Member, and an upper, Arnak Member. The Ivik Member is characterized by interbedded units of sandstone and shale, commonly arranged in large-scale coarsening-upward cycles, and is exemplified by the lower Kugmallit succession in the Ivik wells (Fig. 50). The Arnak Member is dominated by sandstone units, separated by thin shale units. Gamma-ray log traces commonly show a blocky log trace throughout this member. Grain size in the sandstones ranges from very fine to conglomeratic, and, like the other coarse clastic formations in the Tertiary, the clasts are dominated by chert and quartz. Some bentonite beds are present but are not common. The shales are typically silty to sandy. Cementation of the rock types varies considerably, from well cemented in the Ivik area to weakly consolidated in some of the nearshore wells.

Depositional environment

The Kugmallit Formation is a typical prograding deltaic succession, with delta-front coarsening-upward cycles at the base, succeeded by middle delta-plain and upper delta-plain channel-dominated sediments. As mentioned above, some of the older delta-front cycles actually are part of an older progradational delta complex; however, some are part of the Kugmallit progradation. Northward, under the Beaufort Sea, the Kugmallit Formation is composed entirely of delta-front cycles (e.g., in the Isserk–Issungnak area). In the Netserk area the formation begins to thin and also is shalier than it is to the east. North of Netserk, in the Tarsiut area, the equivalent interval is shale-dominant with several sandy units that are distal delta-front deposits. Farther north, in the Kopanoar–Nerlerk area, Kugmallit-equivalent strata consist of slope and basinal deposits (Dixon et al., 1984, 1985, in press).

Age

Kugmallit strata that contain substantial marine intercalations have abundant foraminifers of the *Cancris subconicus* and *Turrillina alsatica* Interval Zones (McNeil, 1989). These assemblages are considered to be Oligocene in age. The associated pollens and spores generally are not age-diagnostic, although a few species are considered to indicate an Oligocene age (McIntyre, *in* Dixon et al., 1985). A Late Eocene to Oligocene age-spread is possible for the Kugmallit Formation (Young and McNeil, 1984, p. 24, 25).

Mackenzie Bay Formation

Description

Young and McNeil (1984) defined the Mackenzie Bay Formation as a shale unit that overlies and intertongues with the Beaufort Formation, and also overlies the Kugmallit Formation in places (e.g., at its type location, the Netserk B-44 well). As previously discussed in the section on the Kugmallit Formation these stratigraphic relationships are questioned and it is herein believed that the Beaufort Formation, as used by Young and McNeil (op. cit.), is of questionable validity and that the intertonguing relationship between the "Beaufort and Mackenzie Bay formations" is difficult to prove conclusively. Throughout most of its area of occurrence, the Mackenzie Bay Formation rests abruptly on Kugmallit strata (Fig. 51) (Dietrich et al., 1985). Under Richards Island and the nearshore areas, Mackenzie Bay strata generally are erosionally overlain by the Plio-Pleistocene Nuktak Formation. However, farther seaward, an intervening unit has been identified from seismic and well data, the Akpak Sequence (Fig. 51) (Dietrich et al., 1985).

Shale is the dominant lithology in all the known penetrations of the MacKenzie Bay Formation. A distinctive characteristic of Mackenzie Bay strata is the abundance of pyrite, commonly present as rod-like shapes and some Y-shapes. These pyrite rods probably are replaced burrow-fills. Thin sandstone beds are present in the Netserk area but are not a major component of the total thickness. Seismic correlations indicate that part of the sediment-fill of Demarcation subbasin is Mackenzie Bay strata. Mackenzie Bay strata are up to 1000 m thick in the Isserk–Issungnak area.

Depositional environment

The shale-dominant character of the Mackenzie Bay Formation and its marine microfossils indicate deposition in a prodelta to shelf environment. Reflection seismic data clearly show slope clinoforms within the succession, over much of the outer Beaufort shelf (figure 52B, C, *in* Dixon et al., 1985). The age-equivalent coarse clastic strata identified in the Taglu area (see the section on the Kugmallit Formation) may represent the eroded basin-margin deltaic strata of the Mackenzie Bay Formation.

Age

The Mackenzie Bay Formation contains foraminifers of the *Turrillina alsatica* and *Asterigerina staeschei* Interval Zones, which are dated as late Oligocene to Miocene (McNeil, 1989). Pollens, spores and dinoflagellates are not common in Mackenzie Bay strata, although those identified do suggest a Miocene age (McIntyre, *in* Dixon et al., 1985).

Akpak Sequence

Description

Dietrich et al. (1985) used the sequence analysis approach to define stratigraphic units in the Beaufort – Mackenzie Basin, based on the large amount of reflection seismic data available. Consequently, they recognized a major sequence between the Mackenzie Bay and Iperk sequences, which they called the Akpak Sequence (Fig. 51). Overlying strata unconformably rest on the Akpak succession which, in turn, abruptly and locally erosionally, overlies Mackenzie Bay Formation strata. The Akpak Sequence is present only under the Beaufort shelf north of a line drawn between the Pullen E-17 and Adgo H-29 wells. A thin erosional remnant is believed to be present in Netserk B-44, between log depths 425.2 and 577.6 m (1395-1895 ft) (Young and McNeil, 1984, identified this interval as basal Nuktak Formation in their figure 5), and is the southernmost known penetration of Akpak strata.

The known Akpak succession is shale-dominant. Pyrite is present but generally is not as abundant as in the Mackenzie Bay Formation. To date no succession of coarse clastic strata, equivalent to the mudstones, have been identified in the wells or by interpretation of reflection seismic. The sequence is about 800 m thick in the Isserk–Issungnak area.

Depositional environment

The shale dominance, presence of marine fossils, and the identified clinoforms on reflection seismic point to deposition in shelf, slope, and basinal environments. No deltaic complex has been identified for this sequence.

Age

The Akpak sequence contains foraminifers of the *Cibicides* sp. 800 Interval Zone, which is dated as Late Miocene (McNeil, 1989). Palynomorphs and dinoflagellates are very similar to those found in the Mackenzie Bay Formation and are dated as Miocene (McIntyre, *in* Dixon et al., 1985).

Nuktak Formation/Iperk Sequence

Description

Unconformably overlying a number of the older Tertiary units is the Nuktak Formation (Young and McNeil, 1984). This unit is equivalent to the Iperk Group of Jones et al. (1980) and the Iperk Sequence of Dietrich et al. (1985). Overlying the Nuktak–Iperk beds is a thin veneer of Pleistocene–Holocene sediment. The Storm Hills gravels, mapped as Beaufort Formation by Norris (1981d), are probably part of the Nuktak–Iperk succession. The topographic expression of these gravels indicates that they rest on a very low-angle, seaward dipping surface, and that they unconformably overlie Reindeer and Kugmallit strata of the nearby Caribou Hills. These physical attributes and the lithology of the gravels strongly suggest correlation with the Nuktak-Iperk succession. With the recently identified Pliocene age for the Beaufort Formation (Fyles, pers. comm., 1990) in the type area, it now seems certain that the Nuktak-Iperk succession is correlative with the Beaufort Formation.

Under Richards Island the Nuktak Formation consists of two members, a lower, gravel member, and an upper, mud member (Young and McNeil, 1984). Together these members range in thickness from a few tens of metres to over 200 m. The succession thickens rapidly seaward. In the vicinity of the Kenalooak J-94 well, the equivalent Iperk Sequence is up to 5000 m thick. The Iperk Sequence thickens rapidly across a hinge zone that Dixon and Dietrich (*in* Dixon et al., 1985, figures 2 and 52A) called the Arctic Platform Hinge Line.

Nuktak-Iperk strata generally are unconsolidated throughout their known area of occurrence. On reflection seismic data the Iperk Sequence is seen as a relatively unstructured, prograding succession (Fig. 53). Topset, foreset, and bottomset reflections of shelf to basin clinoforms can be traced across the Beaufort shelf (Fig. 53). In general, the topset beds contain mostly sand and gravel, although the more seaward ends of the topsets begin to contain more mud and silt. Foreset beds are predominantly mud and silt and the bottomset beds contain interbedded mud and sand, with sand becoming less common when more distal to the foresets.

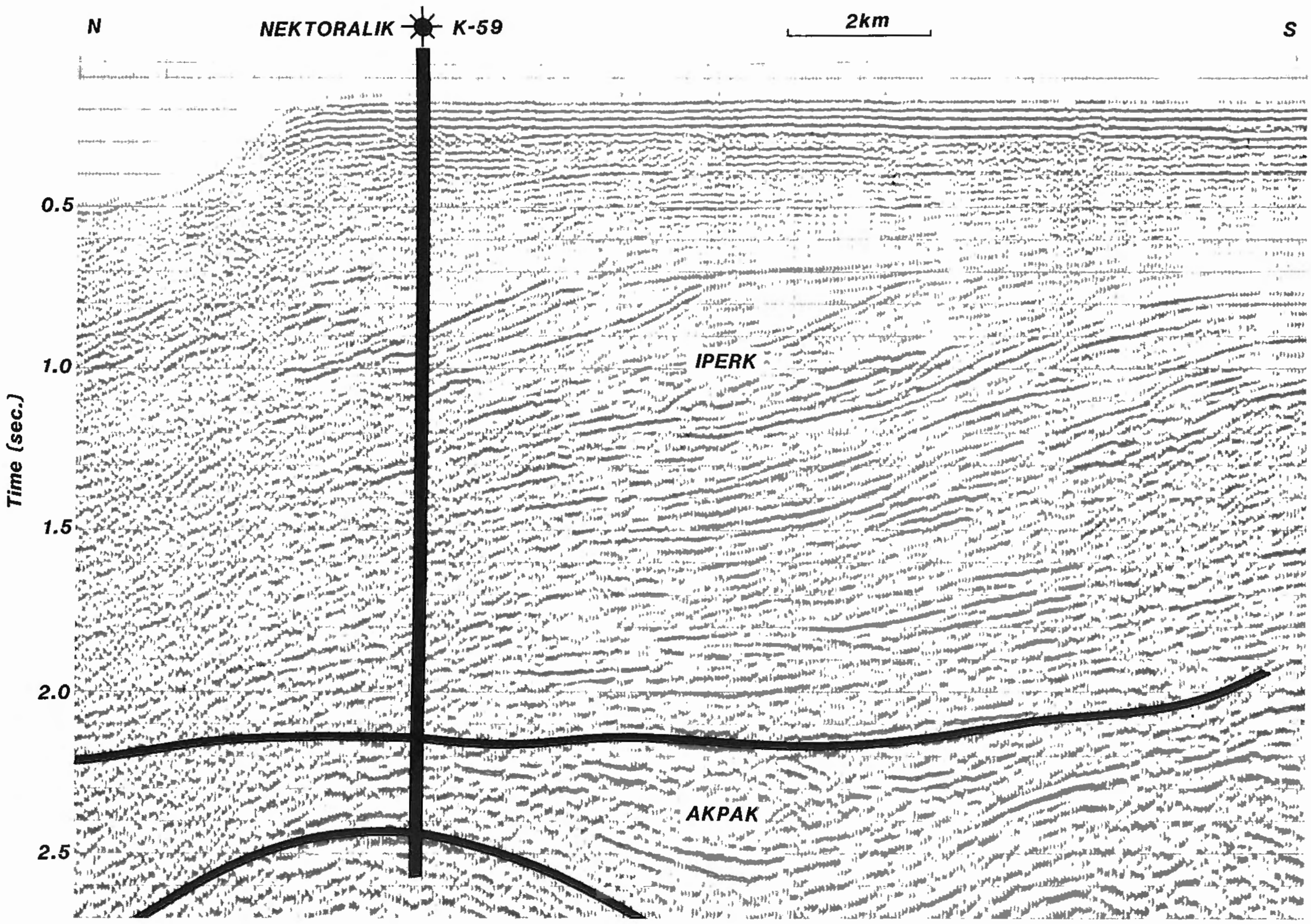

Figure 53. Reflection seismic profile of the Iperk Group/Sequence adjacent to the Nektoralik K-59 well. Note the large-scale slope clinoforms.

Depositional environment

The relatively simple progradational nature and lithology of the Nuktak–Iperk succession suggest an areally large delta complex situated over the eastern part of the Beaufort shelf. Coarse clastic sediments extend seaward as far as the foresets, suggesting that the delta may have fed coarse sediment directly into the deeper water basin during some phases of delta development. The occurrence of interbedded mud and sand at the foot of the foreset beds and beginning of the bottomset beds is suggestive of deposition by sediment gravity-flow, such as turbidity currents and debris flows. These interbedded units appear to extend along the entire length of the Iperk base-of-slope, forming a sediment apron rather than discrete submarine fans. However, it is possible that there are a number of coalesced small fans that are now difficult to identify individually.

Age

The Nuktak–Iperk strata contain foraminifers of the *Cribroelphidium* Assemblage Zone, which is Pliocene to Pleistocene in age (McNeil, 1989). The flora is not very distinctive and contains elements that are common today in the arctic and subarctic regions and are not age diagnostic. Bujak and Davies (*in* Dixon et al., 1984) suggested that the basal part of the Iperk Sequence in the Kopanoar M-13 well could be as old as Late Miocene.

Herschel Island Formation

Description

Some of the cliffs along the Yukon coast contain Pleistocene gravel, sand, and mud of the Herschel Island Formation (Naylor et al., 1972; Johnson et al., 1976). In the vicinity of King Point these deposits are overlain by a late Wisconsin till (Hughes, 1972; Johnson et al., 1976). Young and McNeil (1984, p. 30) felt that the Herschel Island Formation is younger than the Nuktak–Iperk succession. However, these authors appear to have included glacial tills within the Herschel Island Formation, although Johnson et al. (op. cit.) make no mention of glacial till deposits within the formation. Furthermore, the Herschel Island strata appear to have been folded by ice-push and are overlain by till, indicating that they may be inter- or pre-glacial in origin. Johnson et al. (op. cit.) suggested that equivalents of the Herschel Island Formation are present in the subsurface of the Mackenzie Delta/Tuktoyaktuk Peninsula area, based on the common occurrence of *Elphidium* spp. The implication of these points is that the Herschel Island Formation probably is partly equivalent to the Nuktak Formation.

Herschel Island strata are up to 60 m thick but nowhere has the base been seen. They consist of interbedded gravel, sand, silt, and mud. Crossbedded sands are common and bivalve shells have been noted in some units.

Depositional environment

Johnson et al. (1976) described a mixture of marine and nonmarine strata from the Herschel Island Formation, indicating that the overall depositional environment probably was a coastal plain.

Age

The relatively abundant foraminifers recovered from the Herschel Island Formation indicate a late Pleistocene age, according to Johnson et al. (op. cit.). Naylor et al. (1972) also identified the strata of the coastal cliffs as Pleistocene.

Shallow Bay Sequence

Description

Late Pleistocene to Holocene strata on the Beaufort shelf were named the Shallow Bay Sequence by Dietrich et al. (1985) and have been identified on reflection seismic sections of the Mackenzie Trough (an ice-scoured depression on the western Beaufort shelf), where they lie erosionally on older strata. There, the sequence is estimated to be up to 400 m thick. However, in the shelf areas, Shallow Bay strata are not readily differentiated from the underlying Iperk Sequence, due to their thinness and lack of resolution on multifold reflection seismic sections. In the shelf areas, high-resolution reflection seismic data are required to identify the Shallow Bay strata. The sequence consists of interbedded mud, silt, sand, and gravel. It is assumed that the modern Mackenzie Delta deposits are part of the Shallow Bay Sequence. Detailed descriptions of Holocene strata can be found in Vilks et al. (1979) for the Beaufort shelf, and in Mackay (1963) for the Mackenzie Delta.

Depositional environment

Shallow Bay strata were, and are continuing to be, deposited as deltaic, shelf/prodelta, slope, and basinal sediments.

Age

Shallow Bay strata may include glacial sediments and, therefore, may be as old as late Pleistocene, but probably are mostly Holocene.

CRETACEOUS TO PLEISTOCENE DEPOSITIONAL HISTORY

Dixon (in press b) recognized three tectonic phases during Cretaceous to Tertiary development of the area: a Berriasian to Aptian phase dominated by rifting; a late Aptian to Albian phase, when rifting and compression were active; and a Late Cretaceous to Tertiary phase, when compressional tectonism was dominant.

Berriasian to early Aptian strata form a discrete sedimentary assemblage, consisting of easterly and southeasterly derived, texturally mature clastic rocks, deposited in an epicratonic setting. Balkwill et al. (1983) recognized that the northern Yukon stratigraphy has many similarities to north Alaskan stratigraphy, and concluded that pre-Barremian strata were probably deposited in part of a large depositional area, which they referred to as the Brooks–Mackenzie Basin. During this period of deposition, a broad, sandy strandline to inner shelf area extended southwest from the Tuktoyaktuk Peninsula through the Richardson Mountains into the northern Ogilvie Mountains, then changed trend to approximately north-south (Fig. 54 illustrates the interpreted paleoenvironments for late Berriasian time). The sandy facies grade northwestward and westward into mud/silt facies of middle to outer shelf origin. There is no evidence of the two-sided depositional trough, advocated by Jeletzky (1971a, 1974, 1975b), during this period of time. During the late Valanginian to middle Hauterivian, large quantities of coarse clastic sediment were supplied to the eastern part of the Brooks–Mackenzie Basin, and a major delta developed in the area of the Tuktoyaktuk Peninsula. The large volume of sediment may reflect increased fault activity along the main rift zones.

The Aklavik Arch Complex was an active feature during Berriasian to middle Hauterivian sedimentation. This is evident from the rapid thickness increases of strata across the northwest bounding faults, especially well documented along the Eskimo Lakes Arch element (Young et al., 1976; Dixon, 1982), and the tendency of shoreline or nearshore facies to parallel the arch trend. Also, numerous erosional unconformities are present within strata on the various elements of the arch, evidence of periods of uplift.

Late Hauterivian transgressive beds have a distinct facies distribution (Fig. 29). Thick, nearshore sandy beds are present on the east flank of the Richardson Mountains, and on the east flank of the Romanzof Mountains shelf sands are present. In the intervening areas mud and silt are present. During the Barremian to early Aptian, easterly derived sediments were dominant. However, pre-Albian erosion has removed considerable amounts of Barremian–Aptian strata west of the Richardson Mountains; consequently, the western facies are unknown. The sub-Mount Goodenough unconformity on the eastern flanks of the Romanzof Mountains truncates progressively older strata in a northerly to northwesterly direction. These stratigraphic relationships could indicate the presence of a northern or northwestern positive structural element comparable to the Alaskan Barrow Arch.

During most of the Barremian and into the Aptian, mud deposition on a broad shelf prevailed over most of northern Yukon. However, along the northwest flank of the Eskimo Lakes Arch, nearshore to nonmarine strata were deposited (Rat River and Atkinson Point formations). Barremian to Aptian deposits extend farther onto the craton than previous deposits, indicating a major transgression.

A late Aptian/Early Albian transgression further extended depositional limits onto the North American craton. In northern Yukon, a sinuous trend of depositional troughs developed, which, from north to south, consist of the Blow, Keele, and Kandik troughs (Fig. 55). Although given separate names, these troughs appear to have been part of a continuous area of Albian basinal deposition in which a thick succession of sediment gravity-flow deposits accumulated. These troughs were filled principally from the west and northwest, from the uplifted and folded terranes of the Brooks Range Geanticline (Fig. 55) (Young et al., 1976; Dixon, 1986a, b). Some Albian volcanism is indicated by the presence of a few bentonitic beds in the Arctic Red and Horton River formations. These airborne volcanic sediments presumably were derived from volcanic centres in either the Cordillera or the Arctic Islands. Albian deposition also marks the beginning of the

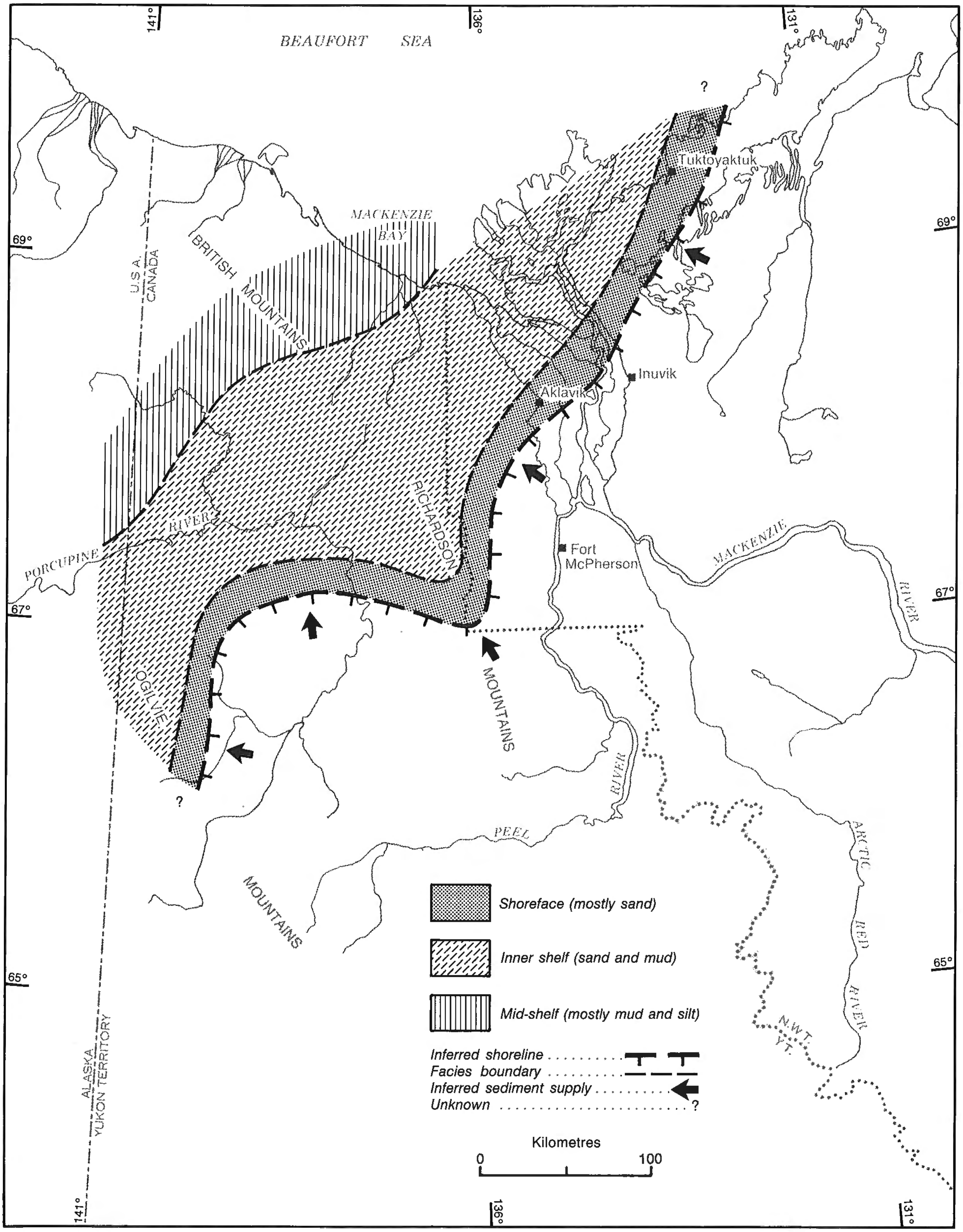

Figure 54. Distribution of late Berriasian depositional environments (no palinspastic restoration).

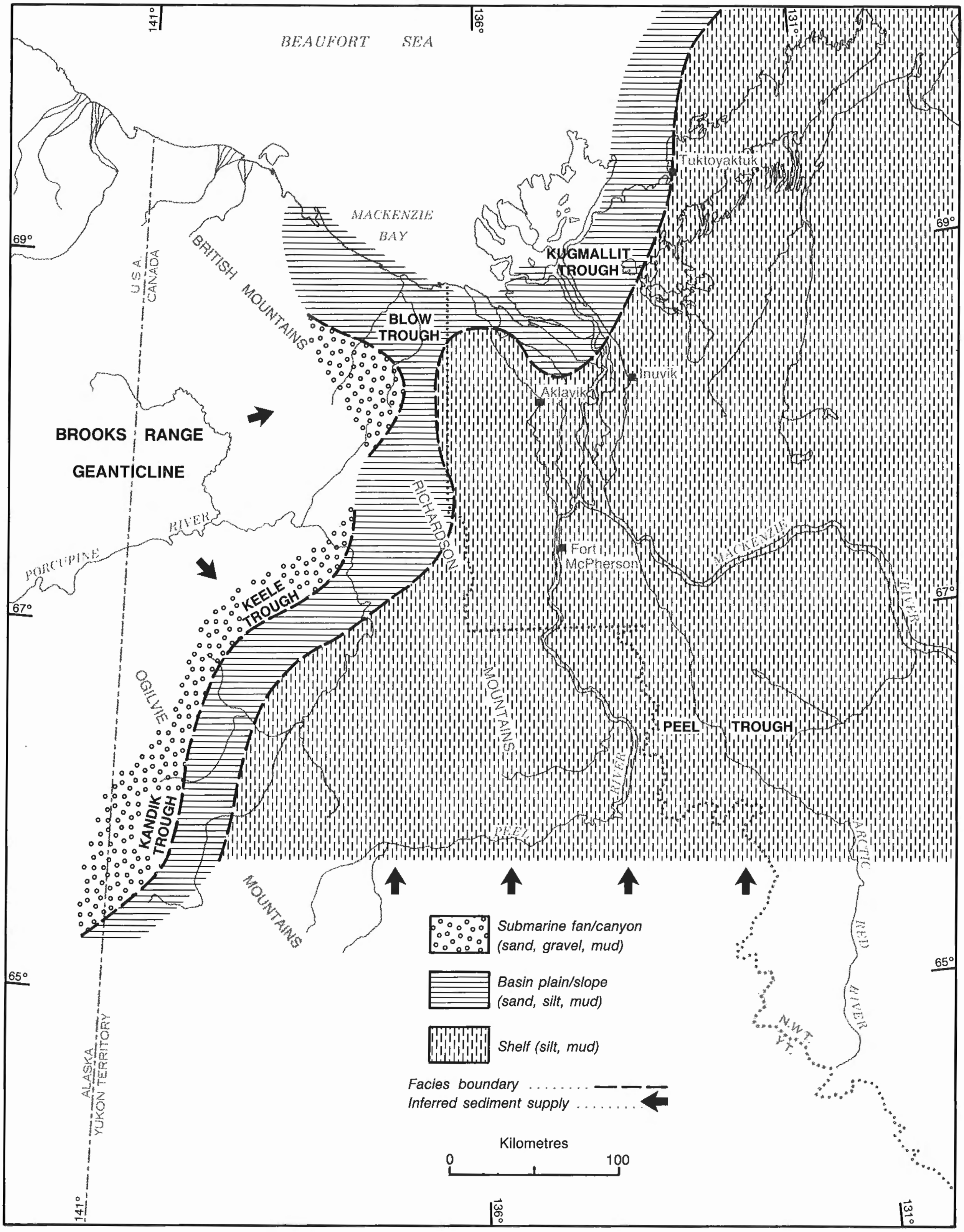

Figure 55. *Distribution of earliest Albian depositional environments (no palinspastic restoration).*

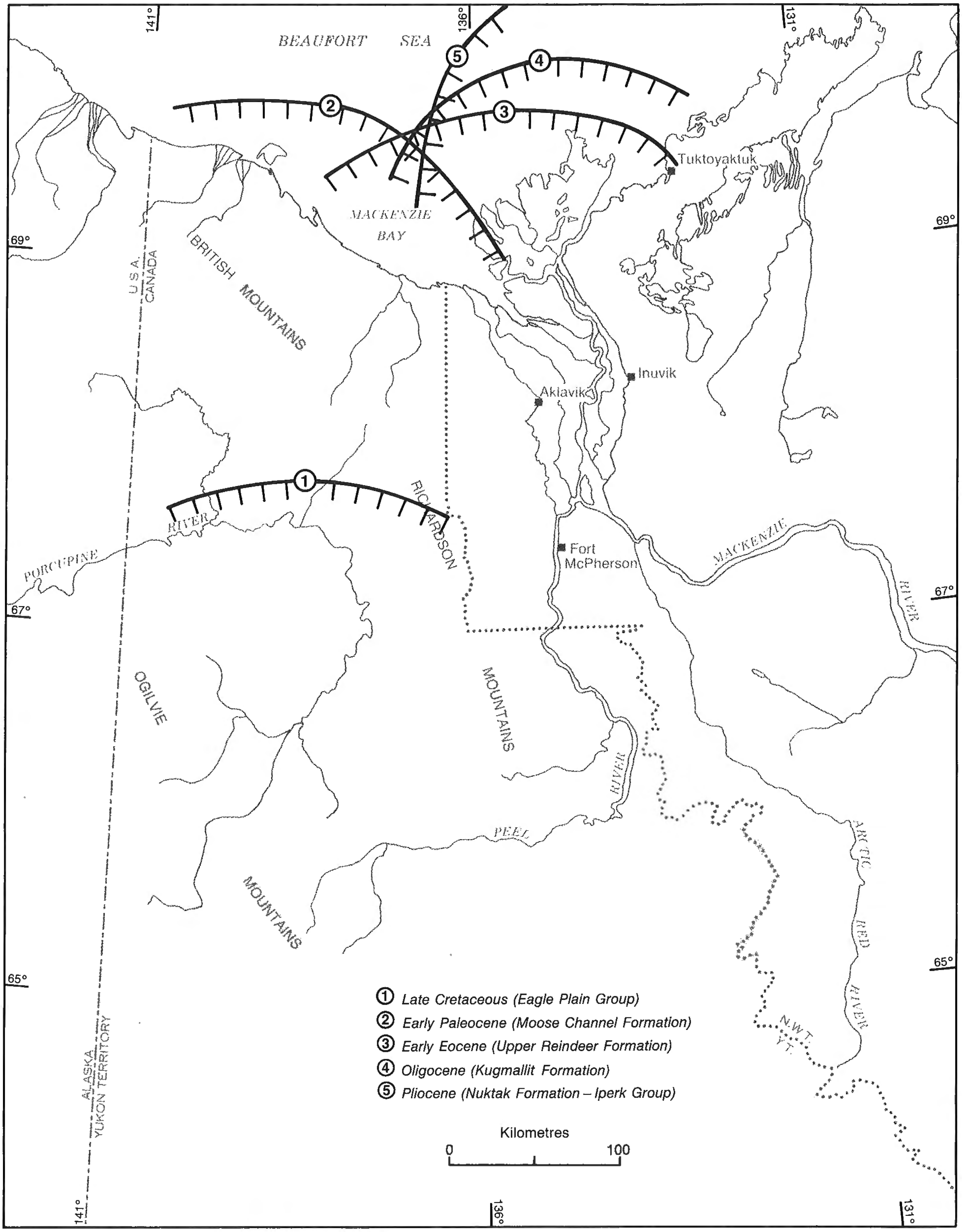

***Figure 56.** Maximum basinward positions of delta-front/inner shelf sands from Late Cretaceous to Pliocene time. Miocene deltaic rocks have not been identified to date, although the thickest accumulations of Miocene strata are in the west Beaufort Sea area.*

development of the Peel Trough foreland basin, in front of the Cordilleran foldbelt. Arctic Red shale and Trevor Formation sandstone were deposited in the Peel Trough and were derived from the south.

The western-derived clastic deposits in the basinal troughs and the presence of the Peel Trough are the first significant features related to Cordilleran compressional tectonism seen in the northern Yukon and adjacent Northwest Territories. However, the Kugmallit Trough, and possibly the Blow, Keele, and Kandik troughs, appear to have been initiated as grabens or half grabens (see the reflection seismic interpretation of Cook et al., 1987, across the Eskimo Lakes Fault Zone), related to continental breakup.

A major unconformity separates Albian from Upper Cretaceous strata throughout the northern Yukon and adjacent District of Mackenzie (Fig. 41) (Dixon, 1986b). The contrast in degree of lithification between Upper and Lower Cretaceous strata across this unconformity has made the plane of unconformity a regional detachment surface in the northern Yukon and in the offshore succession. During the Late Cretaceous and Tertiary, the Blow–Keele–Kandik troughs had been infilled, or at least were less prominent features, and sediments were derived principally from the south and southwest, where the Cordillera was being thrust faulted and uplifted. Late Cretaceous sediments were deposited principally within foreland basins on the craton (Fig. 56). One of the notable sedimentological features of this succession is the abundance of organic-rich mudstones, deposited in areas of low oxygen, probably as outer shelf to slope deposits, in the northernmost areas of the Yukon and adjacent Northwest Territories (Boundary Creek and Smoking Hills formations).

By late Maastrichtian time deposition was mostly on the thermally subsiding continental margin. The combination of thermal subsidence and tectonic loading from the south created the right conditions for the deposition of large delta complexes in the Beaufort–Mackenzie Basin. In effect, the continental margin became the foreland basin of the rising Cordillera. During the early Tertiary the locus of deltaic deposition migrated in a general eastward to northeastward direction across the Beaufort shelf (Fig. 56). An unconformity that developed during the Middle Eocene appears to be related to major compressional tectonism in the Cordillera, and some possible strike-slip motion on the Rapid Fault Array. Deformation during the Late Eocene to Late Miocene was less intense.

The final depositional phase extended from the latest Miocene until the present. Under the Beaufort Sea this phase is represented principally by the Iperk Sequence, and, to a lesser extent, by the Holocene Shallow Bay Sequence. Previous Tertiary delta complexes were centred over the central and western Beaufort areas, whereas the Iperk depocentre is located under the eastern Beaufort Sea, off the mouth of Amundsen Gulf (Fig. 56). Holocene deposition has switched back to the central area. The Iperk succession is characterized by a simple, relatively unstructured, prograding wedge of clastic sediment. While minimal tectonic activity appears to have been recorded in the Iperk Sequence in the eastern area of its occurrence, equivalent strata in northeastern Alaska and parts of the western portion of the Canadian Beaufort Sea are involved in folds and thrusts.

SUMMARY AND CONCLUSIONS

Cretaceous to Holocene deposits are almost entirely clastic and can be divided into a number of sandstone- and mudstone-dominant units of member and formational rank. Berriasian to early Aptian strata were deposited on an epicratonic shelf, with their provenance to the east and southeast. Late Aptian to Albian strata reflect the increasing influence of tectonism in the Cordillera to the west and south, as well as a continuation of rift tectonics associated with the formation of the Canada Basin. During the Albian a depositional, and probably bathymetric, trough extended through northern Yukon and into the Kandik area of Alaska. This Early Albian trough was filled principally from the west, but much of the later Albian sediment was southerly derived and was trapped in foreland basins in front of the rising Cordillera, south of the basinal troughs. Since the Cenomanian, sediment supply has been mostly from the tectonic uplands of the Cordillera. Cenomanian to middle Maastrichtian deposition was mostly on the craton, but, since late Maastrichtian time, deposition has been concentrated on the continental margin bordering the Arctic Ocean.

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