GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA
OPEN FILE 2396

PRELIMINARY INTERPRETATION OF THE 1989 FGP DEEP SEISMIC REFLECTION PROGRAM IN THE WESTERN BEAUFORT SEA

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August 1991

Introduction

A total of 1000 km of deep seismic reflection data have been collected in the Beaufort Sea-Mackenzie Delta region of Arctic Canada as part of the Geological Survey of Canada's Frontier Geoscience Program. The reflection data was collected in three separate acquisition programs, including an onland survey in 1986 and marine surveys in 1987 and 1989. The first two seismic data sets (collected in 1986 and 1987) were released in GSC open files 1549 and 2106. The third and most recent acquisition program (in 1989) consisted of 4 marine profiles (Lines 89-1, 2, 3, 4) totalling 251.6 km of data, collected in the western part of the Beaufort Sea, offshore northern Yukon (Fig.1). This open file describes the acquisition, processing and preliminary interpretations of the four 1989 lines, and includes uninterpreted versions of the final stacked sections (Figs. 2a - 5a), migrated sections (Figs. 2b - 5b), an interpreted version of the stacked sections (Figs. 2c - 5c), vertically condensed displays of the stacked sections (Figs. 2d - 5d), and a shotpoint location map at 1:250,000 scale (Fig. 6).

Acquisition and Processing

The 1989 marine data was collected (under contract) by Geophoto Surveys Ltd. (Halliburton Geophysical) using the seismic vessel M/V Edward O Vetter. An HGS Titan 1000 recording system was used to record data from a 480 channel, 3000 m streamer towed at a depth of 12 m. The seismic source was an 86 m wide tuned airgun array with a total volume of 118 L. Thirty fold data were recorded from 50 m shot intervals. Four ms data were recorded to the following record lengths: Line 89-1, 24 seconds; Line 89-2, 25.5 seconds; Lines 89-3 and 4, 16 seconds.

The data processing included 4:1 adjacent trace mixing, shot and receiver domain velocity filtering, designature, velocity analysis every 2 km, 30 fold stack, time variant filtering and scaling and FK migration. A time-compressed display of the stacked sections (Figs. 2d - 5d) also included an amplitude scaling designed to visually enhance higher amplitude reflections. Although the overall quality of the processed sections is good, the velocity filters and trace mixing may have attenuated some steeply dipping primary reflections on segments of the data set. Reprocessing of portions of the data set is underway to evaluate this possibility, and to attempt to improve the imaging of structurally complex areas. Digital data tapes of the raw data are available at ISPG, Calgary.

Interpretation

The 4 marine profiles are located in the southwestern part of the Cretaceous-Tertiary Beaufort-Mackenzie Basin. The line locations (89-1, 2, 3 and 4) are illustrated on Fig. 1, superimposed on a regional trend map of upper crustal structures within the basin. The line locations were selected to provide images of the structure of the basin fill and underlying crust in a part of the basin known to be highly deformed. Specific geological considerations that provided the focus for this program included questions on the thickness of the basin fill, structure of Tertiary faults, folds and unconformities, detachment levels, deep structure of the Demarcation sub-basin and Herschel High, and the thickness and deformation of the crust below the basin fill. In addition, the longer recording times on two of the lines provided a test for possible seismic imaging of intra-mantle reflections.

The geological setting of the Beaufort-Mackenzie Basin has been described in many papers, with a regional summary recently published by Dixon and Dietrich (1990). The Tertiary stratigraphy and structure of the westernmost part of the basin was described by Dietrich et al. (1989a). One of the 1987 deep seismic reflection lines (87-4), located in the western part of the basin, was intersected by Line 89-4. The interpretation of Line 87-4 was discussed by Dietrich et al. (1989b).

The following section presents interpretations of each of the 4 lines. The discussions refer to the stacked seismic sections, except where noted.

Line 89-1

Line 1 is a 37.8 km long, southwest-northeast oriented profile crossing a portion of the southwestern flank of the basin, east of Herschel Island (Figs. 1, 2). A prominent, angular unconformity imaged in the upper part of the profile, dips basinward across the section, from reflection times of 1.0 to 3.0 seconds (approx. 1 to 4 km depth). The unconformity, identified from nearby well control at Adlartok (Fig. 1), is Middle Eocene in age (base of the Richards sequence) and forms a major tectonostratigraphic boundary between upper and lower Tertiary strata in this part of the basin. The unconformity truncates progressively older strata towards the southern margin of the basin. Along the length of Line 1, strata subcropping below the unconformity are Paleocene fluviodeltaic beds of the lower Aklak sequence. The stratigraphic identification of deeper (older) rocks in this area is not constrained by existing well control. Beneath the southern half of the section, from SP 750 to 500, a near-continuous, locally high amplitude reflection dipping basinward from times of 1.5 to 3.5 seconds appears to be a sequence boundary, locally downlapped by overlying reflections. This unconformity may be the top of the Paleocene Fish River sequence.

Deeper in the section, three relatively high amplitude events occur between travel times of 3 and 7 seconds in the southwest half of Line 89-1. The first, a continuous reflector, dips basinward from 3.4 seconds (5.5 km) at SP 855 to 5.5 seconds (11 km) at SP 450. A straight-line up-dip projection of this reflector intersects the Roland Bay well (Fig. 1), 17.5 km from SP 855, at very shallow depths, suggesting a possible correlation with a sandstone-shale contact at the base of the Fish River sequence (Upper Cretaceous Cuesta Creek Member). An alternative correlation, and the only other high velocity sandstone intersected in the Roland Bay well, is a 70 m thick Lower Cretaceous sandstone at the base of the Mount Goodenough Formation.

The second high-amplitude event is a sequence boundary (onlap surface), imaged between SP 750 and 550 at times of 4.5 to 6.0 seconds. This could be one of several major unconformities (known from well and outcrop data) within the Cretaceous section (e.g. the bases of the Fish River, Boundary Creek or Mount Goodenough sequences), but the present interpretation favours the unconformity at the base of the Upper Cretaceous Boundary Creek Sequence (see Line 89-2, Fig. 3c). Reflections below this boundary (down to the base of the section) are less continuous and weaker in amplitude than those above.

The third high amplitude event extends from 6 seconds at SP 855 to 7 seconds near SP 600. This undulatory reflection appears to truncate overlying discontinuous reflections, suggesting that it may be a structural discontinuity such as a décollement zone (see below).

Beneath the northern half of the seismic profile, the Beaufort-Mackenzie Basin succession may extend down to 7.0 seconds (14 or 15 km). The interpretation of up to 14 or 15 km of Upper Cretaceous to Tertiary clastic sediments in the basin depocentre is consistent with similar estimates of post-rift basin-fill thickness beneath other parts of the Beaufort Sea (Dietrich et al. 1989b).

Most of the reflections imaged along Line 1 dip basinward (northeastward) with steeper dips occurring below the Middle Eocene unconformity. A partially eroded syncline occurs below the unconformity from SP 200 to 500. The low relief syncline and paired anticline at the northeast end of the section are the down-plunge extension of a northwest-southeast trending thrust-cored fold, one of many lower Tertiary-cored folds that form a regional arcuate fold and thrust belt (Fig 1). The northeast flank of the fold crossed by Line 1 contains complex and variably dipping reflection and diffraction patterns, indicating the fold is asymmetric and probably fault-cored. The compressional folding and associated uplift evident along this line are the result of regional Early to Middle Eocene tectonism across the western part of the basin and adjacent northern Yukon (Dietrich and Lane 1991). Minor Late Miocene deformation is also evident along this line from the low relief folding of Oligocene strata from SP 150 to 350, below 0.5 seconds travel time. A thin cover of flat-lying, undeformed Quaternary deposits above 0.5 seconds unconformably overlies the gently deformed Oligocene strata along the length of Line 1.

Although the position, on Line 89-1, of the sub-Mesozoic unconformity is uncertain, straight-line projection from the geology exposed onshore (Norris 1981) indicates that pre-Mesozoic rocks should intersect the section at travel times no less than about 4 seconds. This is constrained by the absence of pre-Mesozoic rocks among those intersected in the Roland Bay well (Fig. 1). The projection from surface, but just missing the well, is nearly parallel with the seismic fabric in Line 89-1, as well as with the projection of Cretaceous strata from the well into the section. We have interpreted a reflection near 4 seconds (SP 855) as the base of the Upper Cretaceous succession, which coincides with an abrupt boundary between more coherent reflections above, and discontinuous reflections below. A similar reduction of reflection continuity is visible at this level on Line 89-2 (Fig. 3c). In order to accommodate the Lower Cretaceous and Jurassic succession exposed onshore, the Paleozoic succession would have to be deeper, indicating a steeper average dip for the sub-Mesozoic unconformity (as compared to the dip of Cretaceous strata and the expected dip of the unconformity). This could be accommodated by a basinward thickening Mesozoic section, either by onlap or by tectonic thickening. Tectonic thickening is favoured due to a lack of evidence for significant onlap at this level (see Line 89-4, Fig. 5c). It is also consistent with the requirement for décollements at depth on which crustal shortening was transferred to the thrust-cored folds in the Beaufort-Mackenzie Basin. The base of the Upper Cretaceous succession, the Kingak shale, and a Lower Cambrian argillite are recognized regionally as important décollement horizons along which such tectonic thickening may be accommodated. We have interpreted the reflector near 4 seconds (SP 855) as the base of the Upper Cretaceous succession, and expect the deeper horizons to be present also. We therefore interpret the high amplitude undulatory reflection at 6 seconds (SP 855) as a décollement, possibly at the level of the Kingak shale, or the Cambrian argillite.

Below 6-7 seconds, deep crustal reflections dip basinward in the southwest half of Line 1 and are subhorizontal, locally shoreward-dipping, in the northeast half. These orientations reflect the basinward thickening of the overlying Cretaceous-Tertiary succession. Middle and lower crustal reflections are discontinuous and are locally masked by diffractions, suggesting the existence at depth of significant structural complexity. The base of the crust may be resolved between 11 and 12 seconds travel times at two locations (SP 650-820, and SP 360-410). Using stacking velocities, those travel times are equivalent to 32 km depth at the southwest end, rising slightly to 29 km near the centre of the line. In the northeast part of the line, the shallow anticline-syncline pair interferes with deep energy penetration and reflections lose continuity at shallower levels.

As with other lines crossing the basin margin (e.g. Cook et al. 1987, Dietrich et al. 1989b), including Line 89-4, the thickening of basin sediments coincides with thinning of the lower crustal section in a basinward direction. The crustal section near SP 800 consists of an Upper Cretaceous-Tertiary section extending approximately to 4 seconds travel time overlying Lower Cretaceous-Jurassic sediments, which in turn unconformably overly Lower Paleozoic and older sediments exposed onshore (Norris 1981, Lane and Cecile 1989).

Between SP 101 and SP 500, crustal structure is consistent with an Upper Cretaceous-Tertiary section extending to at least 6 seconds and probably 7 seconds travel time. The Jurassic-Lower Cretaceous section appears to taper out basinward, between the thickening younger succession and subhorizontal mid-crustal reflections. An important implication of the foregoing is the apparent basinward thinning of the pre-Middle Cretaceous crust from 7.5 seconds (23.6 km) thick near SP 850 to 4 seconds (13.2 km) thick near SP 400, a horizontal distance of 22.5 km. This thinning coincides with the change in structural style in the shallow succession from thrust repetition of units, seen onshore, to detached thrust-cored folding offshore. In the central Beaufort, these folds appear to be detached on a décollement zone at 6-7 seconds travel time (see Dietrich et al. 1989b). In Line 1, discontinuous subhorizontal reflections between 6.9 and 7.4 seconds (SP

101-450) may be such a décollement. Several basinward-dipping reflections in the lower crust may be features relating to Jura-Cretaceous rifting, but they are too poorly imaged to interpret with any confidence.

Line 89-2

Line 2 is a northwest-southeast oriented, 84.5 km long profile which intersects Line 1 east of Herschel Island. Line 2 is oriented parallel to the basin margin and local strike of the Tertiary foldbelt in order to maximize deep signal penetration.

The Middle Eocene unconformity is clearly imaged above 1.5 seconds along the length of Line 2. Similar to Line 1, the unconformity is locally angular, with significant truncation of underlying strata. Lower Tertiary strata of the Taglu, Aklak and ?Fish River sequences subcrop below the unconformity, with generally younger beds preserved towards the northwest end of the section. Local subcrop patterns northwest of SP 1000 are complicated by the juxtaposition of variably eroded fault-bounded blocks below the unconformity. Northwest of SP 200, high amplitude reflections between 2.8 and 4.0 seconds can be directly correlated to coal-bearing strata within the Paleocene-Early Eocene Aklak sequence, penetrated by the Natsek E-56 well to the west.

Reflections below the Middle Eocene unconformity are horizontal to gently inclined, southeast of SP 500. Several sub-parallel, semi-continuous reflections extend across the southeastern half of the section, between reflection times of 3.0 and 5.5 seconds. As interpreted for Line 1, the deeper intervals (between reflection times of 4.0 and 5.5 seconds) may consist of Cretaceous marine strata.

Lower Tertiary strata below the Middle Eocene unconformity are disrupted by numerous normal faults beneath the northwestern half of the section. Some of the faults offset the Middle Eocene unconformity but the displacements and deformation in Upper Tertiary strata are minor in comparison to those below the unconformity. The faults between SP 500 and 1000 have normal displacements and are slightly listric in shape. All of the faults appear to be detached above sub-horizontal reflections below 3.5 seconds. The main zone of detachment appears to be within a reflection interval between 3.5 and 4.5 seconds (6 to 8 km depth) interpreted (stratigraphically) to be within Paleocene shales of the lower Fish River sequence. A complex fault zone between SP 250 and 500 locally obscures the geology. Lower Tertiary strata within this zone are intensely deformed and locally steeply dipping. The deep structure of this zone is not clearly imaged but the appearance of discontinuous sub-horizontal reflections below 4.0 seconds suggest a detached fault zone similar to the faults to the southeast. The faults and fault zones crossed by Line 2 are oriented in southwest-northeast directions, approximately perpendicular to the local strike of the Early Tertiary folds and thrust faults (Fig. 1). Both the faults and folds appear to have developed at the same time during Early to Middle Eocene tectonism.

The faults would then be northwest-southeast extensional zones accommodating contemporaneous northeast-southwest shortening.

At deeper levels, imaging of crustal features varies along the line. Northwest of SP 600, deeper images degrade due to noise introduced by structural complexity at shallow levels. Between SP 700 and SP 1100, lower crust is characterized by numerous subhorizontal, discontinuous reflections. In particular, one high amplitude reflection (SP 740-900) extends for about 8 km at a travel time of 9.5 seconds (approximately 24 km depth). A corresponding reflection is not well imaged on Line 1, where a series of seaward-dipping reflections extend from 9.5 to 11.2 seconds.

Southeast of shotpoint 1200, and at travel times greater than about 6.5 seconds the lower crust is imaged as an array of diffractions and variably dipping reflections indicative of the presence of abundant discontinuities and complex structures. Any interpretation of these features must be highly speculative. However, their location confined to an area east of Kay Point (Fig. 1), and their stratigraphic position below continuous reflectors interpreted as Upper Cretaceous and Lower Tertiary strata altogether suggest that the deep reflections and diffractions are due to structures relating to the Early Albian rifting event that produced Blow Trough. Additional support for this interpretation comes from the empirical relationship between seismic resolution of the Moho and crust that has been subjected to extension and magmatic activity, (e.g. Allmendinger et al. 1987). This part of Line 2 contains the best image of the Moho obtained in the entire 1989 program. The spatial coincidence of these middle to lower crustal reflections and diffractions with the western margin of the Blow River High (Fig. 1) suggests that the Blow River High formed when the weak, previously rifted lower crust was shortened causing the Mesozoic and Lower Tertiary fill to invert during Tertiary Brookian orogenesis (see Lane 1988). The Eocene crustal shortening is not imaged on this line which is oriented parallel to the strike.

As noted, the best image of the base of the crust occurs at SP 1560-1710 on Line 2, at 13.0 seconds (38 km). A high amplitude reflection at 12.3 seconds below SP 1300 may also be Moho. No other arrivals suggestive of Moho occur until SP 101-300 where relatively high amplitude arrivals occur at 11.5 seconds and 12.3 seconds travel times. It is unclear which, if either, event represents Moho. In a continental margin setting Moho may be imaged as a transition zone over as much as a second of travel time (Allmendinger et al. 1987) so it is equally possible that both reflections comprise the Moho. This uncertainty will be addressed using gravity modelling.

High amplitude reflections at travel times of 18-21 seconds occur at SP 900-1400, and times of 15.5-19.5 seconds at SP 101-500. These travel times correspond to depths of 60-70 km and 45-65 km, respectively. Although mantle reflections originating from approximately 68 km depth have been suggested on the basis of seismic refraction modelling in the Mackenzie Delta area (Zelt 1988), further analysis is required to determine whether the events imaged on Line 2 are intra-mantle reflections or offline reflections of shallow origin.

Line 89-3

Line 3 is an east-west oriented, 79.1 km long profile extending from the northwest end of Line 2 to the Canada-USA border. The western half of the profile extends into the Demarcation Subbasin, a major, east-west trending Upper Tertiary depocentre (Fig. 1).

The stratigraphy of the upper part of the section is well known from previous analyses of seismic and well data in this area (Dietrich et al. 1989a). The Middle Eocene unconformity rises from reflection times of 1.75 seconds at the east end of the section (SP 101) to an erosional edge (near SP 550) below a Late Miocene unconformity at 0.5 seconds. West of SP 750, the Middle Eocene unconformity forms the base of the Demarcation Subbasin, extending down to 3.7 seconds (5.5 km) at the west end of the section. The subbasin fill consists of relatively undeformed, northwest-dipping Late Eocene to Miocene strata. The subbasin fill along Line 3 includes a thin basal section of Late Eocene marginal marine deposits of the Richards sequence and a much thicker overlying section of Oligocene-Miocene marine and nonmarine deposits of the Kugmallit and Mackenzie Bay sequences. Moderately deformed, lower Tertiary to Upper Cretaceous strata underlie the subbasin, with progressively older strata subcropping below the Middle Eocene unconformity towards the west end of the section. The lower Tertiary section includes an eastward-thickening wedge of coal-bearing fluviodeltaic strata of the Aklak and Fish River sequences, characterized seismically by high amplitude reflections. A major Early Eocene unconformity separates the highly reflective strata of the Aklak sequence from overlying, weakly reflective strata within the shale-dominant Eocene Taglu sequence. The high amplitude seismic facies is gradationally underlain by lower amplitude reflection intervals below times of 3.0 to 4.5 seconds. The low amplitude intervals are interpreted to be shale-dominant, lower Paleocene to Upper Cretaceous shelf and slope strata. The Paleocene-Upper Cretaceous section unconformably overlies a major sequence boundary at times of 4.0 to 5.0 seconds (7.5 to 9.5 km).

At the eastern end of Line 3 (centred under SP 200) the Lower Tertiary sequences are folded into an asymmetric anticline. On the migrated section the anticline (which trends northwest-southeast, Fig. 1) appears to be cored by a southwest-verging thrust fault. This compressional structure is detached above sub-horizontal reflections at 5.0 seconds (Fig. 4c). The detachment level is interpreted to occur within Upper Cretaceous shales, at or near the base of the Fish River sequence.

The reflection character of the crust at travel times greater than about 5 seconds is consistent with that of the other lines in this program. Reflections are generally subhorizontal and discontinuous with abundant diffractions. A few mid-crustal reflections are relatively continuous over several hundred shotpoints. At the western end of Line 3 (SP 1300-1679), a series of reflections can be identified between 6.5 and 7.2 seconds travel times. A number of other reflections can be correlated discontinuously across the profile at travel times between 5 and 7 seconds. These reflections are partly masked by diffractions.

Lower crustal reflections are poorly resolved. At SP 1000-1250, some locally continuous reflections occur between 8 and 10 seconds travel times. High amplitude reflections near the east end of Line 3 occur between 10 and 11.5 seconds. They tend to rise westward, subparallel to the trend of overlying discontinuous reflections, but cannot be traced beyond about SP 700. It is possible that this reflection may be Moho, or alternatively a major boundary deep within the lower crust. At the west end of Line 89-3, a few discontinuous reflections near 13 seconds travel time beneath the Demarcation Subbasin, may be Moho at 34-35 km depth. Further interpretation and gravity modelling is expected to clarify the position of the Moho in this area.

Two significant crustal features are the pattern of westward truncation of units beneath Demarcation Subbasin, and the apparent eastward dip of lower crustal reflectors. The truncation angle beneath the Middle Eocene unconformity (base of the subbasin fill) indicates that the eastward component of dip of the Upper Cretaceous sediments in Mid-Eocene time was approximately 15 degrees. A similar landward truncation beneath the southern part of the subbasin is shown in Line 4, indicating that a local high existed south of the subbasin axis, presumably related to Brookian orogenesis. The eastward apparent dip of deep crustal reflections in eastern Line 3 continues to SP 400 in Line 2, where it appears to taper out against the base of the crust. Significantly, these dipping reflectors appear to be truncated by the high amplitude horizontal reflectors between 11 and 12.5 seconds, which may be Moho and near-Moho reflectors. Because we cannot verify the source of the reflections, the tectonic significance of this structure is uncertain. We can speculate that this crustal geometry may define a lateral ramp, or similar structure relating to the culmination of Paleozoic strata exposed in the British Mountains. Alternatively it may be an extensional feature relating to Cretaceous opening of the basin. Whatever its origin, it is apparent that a major lower crustal element present beneath the western Beaufort-Mackenzie Basin tapers out eastward and is absent east of Herschel Island. This feature may be responsible for the localization and southwest vergence of the small thrust-cored fold imaged on Line 3 at SP 200.

Line 89-4

Line 4 is a south-southwest north-northeast oriented, 50.2 km long profile extending across the Demarcation Subbasin and a portion of the adjacent Herschel High, in the westernmost part of the Canadian Beaufort Sea. Lines 3 and 4 intersect at a position within the southeastern part of the subbasin. Line 4 also intersects FGP 87-4 (SP 3467, see Dietrich et al. 1989b) at SP 339.

The stratigraphy of the Demarcation Subbasin fill is similar to that described for Line 3, except that Line 4 contains a thicker section of Richards sequence strata. Reflections of the Richards sequence are discontinous and low amplitude, and are unconformably overlain by higher amplitude, sub-parallel reflections of the Kugmallit sequence. The Middle Eocene unconformity at the base of the Richards sequence occurs at a reflection time of 4.0 seconds (6 km) at the subbasin depocentre, located between SP 520 and 600. Between SP 500 and 820, the Middle Eocene unconformity is underlain by a weakly reflective to non-reflective section interpreted as lowermost Tertiary-Upper Cretaceous strata. South of SP 820, towards the Yukon coastline, the subbasin is underlain by highly deformed, lower Mesozoic and older rocks, characterized seismically by discontinous, variably dipping reflections (similar to that described for Line 3). The unconformity at the base of the (interpreted) Upper Cretaceous section dips basinward from reflection times of 3.0 seconds (at SP 820) to 5.5 seconds (at SP 500). The identification (projection) of both the Middle Eocene and Cretaceous unconformities north of SP 500 is unclear. On the migrated section (Fig. 5b), both unconformities appear to be folded within a broad syncline underlying the deepest part of the Demarcation Subbasin. Farther north, the Cretaceous unconformity appears to flatten into, or is truncated by, a sub-horizontal zone of discontinous, contorted reflections below 3.5 seconds. Previous interpretations of the structure of the Middle Eocene unconformity along the north flank of the Demarcation Subbasin (from other seismic lines in the area) indicate that the Middle Eocene unconformity rises to relatively shallow depths (about 1 km, or reflection times of 1.0 to 1.5 seconds) over the crest of the Herschel High (e.g. Fig. 10 in Dietrich et al. 1989a). Such an interpretation along Line 4 (north of SP 500) appears to require a fault offset of the unconformity to structurally higher levels over the Herschel High. Alternatively, the Eocene unconformity north of SP 500 may be a steeply dipping surface that has not been clearly imaged by the seismic processing applied to this line.

The Herschel High at the north end of Line 4 appears to be a complexly deformed wedge characterized seismically by discontinous, weak reflections and numerous diffractions. The internal structure of the high appears to be very complex and is difficult to interpret in detail with the seismic images on Line 4. Previous interpretations from deep seismic line 87-4 have suggested the high is cored by intensely folded and thrust faulted lower Tertiary strata and is detached above a deep décollement at or near 6.0 seconds (Dietrich et al. 1989b). Much of the deformation within the Herschel High is believed to have developed during the Early to Middle Eocene compression that produced the regional fold and thrust belt, with significant reactivation of Late Eocene to Miocene age.

The Demarcation Subbasin is an asymmetric syncline, with steeper dips on its northern flank and a synclinal axis which is located at progressively landward positions at younger (shallower) stratigraphic levels. Late Eocene to Miocene subsidence and sedimentation within the subbasin was accompanied by relative uplift of the adjacent Herschel High, resulting in complex stratigraphic patterns and depositional facies along the northern flank of the subbasin. The landward migration of the subbasin axis through time may have resulted from uplift and tilting of the northern flank due to progressive uplift of the

Herschel High. The present day expression of the subbasin also reflects a major phase of Late Miocene uplift and erosion, which resulted in significant truncation of Oligocene-Miocene strata around the margins of the subbasin. Relatively flat-lying Plio-Pleistocene beds (above 0.5 seconds) unconformably overlie erosionally truncated and locally tilted Oligocene-Miocene strata.

Middle and lower crustal reflections in Line 4 are poorly resolved. A series of discontinuous high amplitude events can be identified at 4.7 seconds (SP 1050), descending to 6 seconds (SP 600), then possibly rising to the vicinity of 5 seconds (SP 250). These reflections can also be resolved on the migration. This feature may be a major lithological crustal boundary or an important décollement zone. It forms the base of a wedge shaped crustal block in the southern half of Line 4, which contains predominantly lower Paleozoic and possibly Proterozoic rocks (projected from surface exposures), overlain by a seaward-thickening veneer of Jurassic and Cretaceous sediments. This seaward-thickening is accomplished by progressive northward preservation (or southward truncation) of the Mesozoic succession beneath the Middle Eocene unconformity. On the basis of surface exposures, the Paleozoic rocks are highly deformed and steeply dipping, whereas the Mesozoic succession is less intensely deformed and shallowly to moderately dipping (Norris 1981; Lane et al. 1991). Therefore, the Paleozoic rocks underlying part of this profile would be expected to generate abundant diffractions, and the Mesozoic rocks would be expected to generate more coherent reflections. The preserved seismic fabric, within this wedge of Mesozoic and Paleozoic rocks, dips basinward more steeply than the basal reflection which appears to truncate the internal fabric. Several discontinuous reflections occur at deeper levels subparallel to this 5-6 second reflector. The best images occur between SP 500 and SP 700 at travel times near 7 and 9 seconds. Other examples occur at the northern end of the line at 8 and 10 seconds travel time in spite of the fact that deep crustal images deteriorate in the northern and southern ends of the line due to structural complexity at shallow levels.

The overall synclinal form of the lower crustal reflections is due to the effects of crustal loading by the Demarcation Subbasin, enhanced by the velocity effect of the subbasin fill. The base of the crust is poorly imaged in Line 4. Some relatively high amplitude, discontinuous events near 12 seconds at the ends of the line and near 13 seconds beneath the axis of the Demarcation Subbasin may be Moho reflections. If so, they would lie at depths of 35 km over most of the profile, rising to 33 km at the north end.

Discussion

Onshore geology indicates that the continental crust beneath the western Beaufort Sea margin consists of Jurassic and Cretaceous fine-grained clastic rocks unconformably overlying deformed, principally lower Paleozoic, basinal sedimentary rocks (Cecile 1988, Lane and Cecile 1989). The basinal aspect of these older rocks implies that they were deposited on oceanic basement (see Norris 1985). The implication for this discussion is that no conventional cratonic basement exists for this area (compare with Cook et al. 1987). Instead the basement rocks consist of a deformed and metamorphosed continental margin assemblage, possibly accounting for the high reflectivity and well layered appearance, as well as apparent structural complexity of the lower crust in this survey area.

The Demarcation Subbasin is well imaged in Lines 3 and 4 of this survey, and will be the subject of a more detailed future report. The subbasin began to develop rapidly in the Late Eocene to Oligocene. Richards and Kugmallit sequences were deposited in the subbasin contemporaneously with reactivated thrusting and folding in the adjacent Herschel High. Southward migration of the depocentre is clearly imaged in Line 4. The Richards depocentre is below SP 550-600, during lower Kugmallit deposition it was below SP 650-700. Younger deposits show the depocentre migrating progressively towards SP 850 for reflections just below the sub-Iperk unconformity (Late Miocene age) at 0.5 seconds. At travel times less than 2 seconds the basin fill shows predominantly parallel reflections, except for the flexural hinge area towards the southern end of the line. Local south-dipping reflection foresets along the northern subbasin flank (imaged on industry seismic profiles) suggest that the mid-Tertiary extent of the basin was probably slightly farther north. Late Miocene compression and uplift of the Herschel High led to considerable erosional truncation of strata over the crest and along both flanks of the high, removing part of the record of late stage subbasin sedimentation patterns.

Summary and Conclusions

Four deep reflection seismic profiles totalling 251.6 km were collected during 1989 in the western Beaufort Sea. The lines were located away from intense Early Tertiary folds and thrust faults in order to maximize deep signal penetration. The profiles included in this report consist of stacked and migrated sections processed to 24 seconds (Lines 1 and 2) and 16 seconds (Lines 3 and 4). The displays are plotted with a large negative bias on the wiggle traces to lessen the visual impact of the noise, however it also reduces the apparent continuity of some reflections.

Crustal thicknesses vary between approximately 30 km and 38 km in the survey area, but the Moho is poorly resolved in general. At the northwest end of Line 2, and adjacent east end of Line 3, reflections at, or near, the Moho truncate a major zone of eastward-dipping reflectors in the lower crust. The crust has a three-fold structure in this area. The uppermost part, the Beaufort-Mackenzie Basin succession, is well resolved except where folds and faults disrupt seismic continuity. The Demarcation Subbasin developed in the Middle Tertiary as a synclinal depression landward of the partially contemporaneous Herschel High. Seismic character of the subbasin deposits indicates initially rapid subsidence and infilling followed by a period of slower subsidence, and deposition which kept pace with the subsidence. The subbasin fill is unconformably overlain by flat-lying sediments of the Plio-Pleistocene Iperk Sequence.

The middle part of the crust consists of Paleozoic and Mesozoic (Triassic-Lower Cretaceous) sedimentary rocks which can be projected from exposures onshore. The Mesozoic rocks in particular have a variable, continuous to discontinuous seismic reflection character, however they comprise a relatively small proportion of the crust. The lower part of the crust is characterized by discontinuous, subhorizontal to moderately dipping reflections. Interpretations of the lithology annd structure of that part of the crust are particularly speculative. However, the tectonic setting of the region constrains the lower crust to consist of distal continental margin sediments and petrologically oceanic (or transitional) basement, previously deformed, metamorphosed and intruded locally by Devonian plutons during an earlier cycle of consolidation to the North American craton. This is consistent with the well-layered seismic character of the deep crust. In Lines 1 and 4, segments of the middle and lower crust taper seaward, corresponding to an increase in Beaufort-Mackenzie basin sequence thicknesses. These stratigraphic changes coincide with a change in structural style during Early Tertiary crustal shortening, from thrust duplication of strata as exposed onshore to well-developed detached folding typical of the western and central Beaufort-Mackenzie basin.

Some discontinuous, relatively high amplitude reflections in Lines 1 and 4 may be major structural discontinuities, possibly décollement zones which transferred Early Eocene crustal shortening basinward to the arcuate foldbelt, marking the offshore Brookian foreland in the region.

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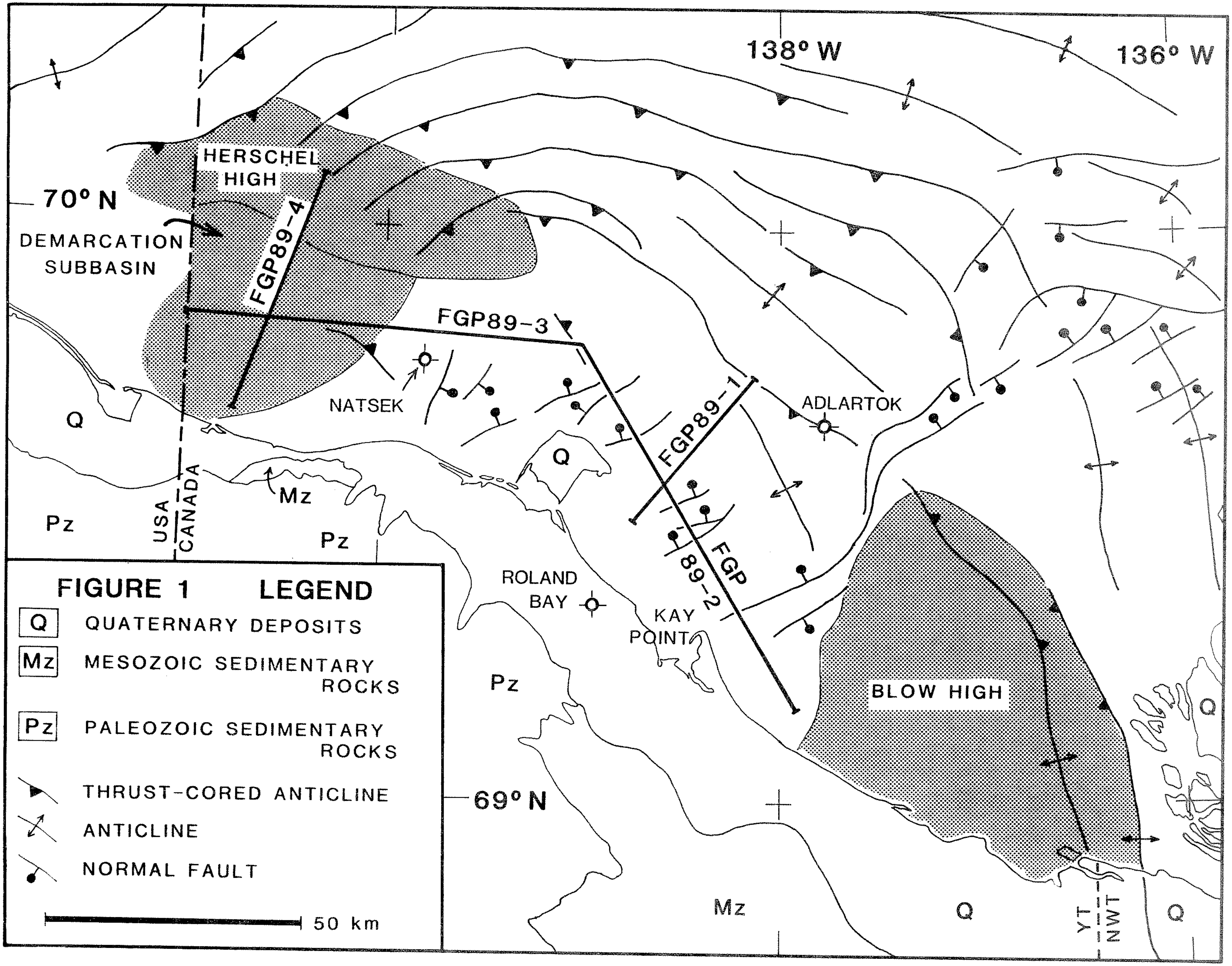

FIGURE 1

LEGEND
Q QUATERNARY DEPOSITS
Mz MESOZOIC SEDIMENTARY ROCKS
Pz PALEOZOIC SEDIMENTARY ROCKS
THRUST-CORED ANTICLINE
ANTICLINE
NORMAL FAULT
50 km
138° W
136° W
70° N
69° N
HERSCHEL HIGH
DEMARCATION SUBBASIN
FGP89-4
FGP89-3
FGP89-1
FGP 89-2
NATSEK
ADLARTOK
ROLAND BAY
KAY POINT
BLOW HIGH
USA
CANADA
YT
NWT
Q
Mz
Pz