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SEISMIC STRATIGRAPHY AND TECTONIC EVOLUTION OF THE FALKLAND/MALVINAS PLATEAU*

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ABSTRACT A new perspective on the geology of the Falkland/Malvinas Plateau (South Atlantic) is derived from a detailed synthesis of 14,000 km of mainly unpublished single-channel and multichannel seismic data, aided by redge-haul descriptions and DSDP data. The Plateau is a foundered complex of continental blocks that were differentially rifted during the opening of the South Atlantic in the Middle Jurassic to Early Cretaceous. Up to 7 km of synrift, transitional, and hemipelagic sediments have been deposited since the Middle Jurassic, largely under the control of a northern marginal fracture ridge. Three major structural lineations outline basement geometry. They are: **1.** a NE–SW tectonic trend marking the eastern edge of the Plateau; **2.** the Falkland Escarpment marginal fracture ridge to the north and nearby grabens that are parallel or subparallel to the approximately E–W Falkland Fracture Zone; and **3.** the western edge of the Maurice Ewing Bank running NW–SE that is related to extensive rifting and volcanic activity in the central Falkland Basin. The complicated geometries of these structural trends are related to triple-junction tectonics when the South American, African, and Antarctic blocks moved apart in the Late Jurassic/Early Cretaceous. We estimate that the Plateau had been lengthened by at least 400 km in an east-west direction, before the initiation of drift at about anomaly M10 time. From the acoustic stratigraphy we have defined four widespread depositional sequences. Three of these have been sampled by DSDP drilling and their bounding unconformities are interpreted to have resulted from: **1.** an early Paleozoic pediplanation; **2.** a post-rift erosional truncation; and **3.** erosion by ocean currents that preceded the establishment of the Antarctic Circumpolar Current near the time of the Cretaceous/Tertiary boundary. Our seismic profiles reveal that in the early Paleogene, migrating sediment drift deposits several hundreds of meters thick were deposited over the whole Plateau. A fourth depositional sequence remains unsampled by drilling. It is bounded below by an intra-Cretaceous unconformity that originated from ocean current activity and its top by the above mentioned C/T erosional surface. Six isopach sediment and basement structure maps which succinctly display the geometries of these sedimentary units are included.

RESUMO ESTRATIGRAFIA SÍSMICA E EVOLUÇÃO TECTÔNICA DO PLATÔ FALKLAND/MALVINAS. Uma nova perspectiva da geologia do Platô Falkland/Malvinas (Atlântico Sul) deriva de uma síntese detalhada de 14.000 km de sísmica de reflexão mono e multicanais, na sua maioria não publicados, em conjunto com descrições de rochas e de perfurações do DSDP. O Platô é um complexo de blocos continentais submersos que foram diferencialmente estendidos durante a abertura do Atlântico Sul no Mesojurássico-Eocretáceo. Um máximo de 7 km de sedimentos sinrifte, transicionais e hemipelágicos foram depositados desde o Mesojurássico, largamente sob o controle estrutural de uma cadeia marginal de zona de fratura. A geometria do embasamento é dominada por três direções estruturais principais: **1.** uma lineação tectônica NE–SW, que marca a borda oriental do Platô; **2.** a cadeia marginal da escarpa das Falklands ao norte e grábens adjacentes que são paralelos ou subparalelos à zona de fratura Falkland com orientação E–W; **3.** a borda oeste do Banco Maurice Ewing, com direção NW–SE, relacionada ao intenso rifteamento e atividade vulcânica na parte central da bacia das Falklands. O complexo arcabouço estrutural da região está relacionado à tectônica de uma junção tríplice, quando as placas Sul-Americana, Africana e Antártica se separaram no Neojurássico-Eocretáceo. Estimamos que o Platô tenha sido estendido por pelo menor 400 km na direção este-oeste antes da iniciação da deriva aproximadamente no tempo da anomalia magnética M10. Quatro seqüências deposicionais de ampla ocorrência foram definidas a partir da estratigrafia acústica, três das quais amostradas em perfurações do DSDP. As inconformidades que as limitam resultaram de: **1.** pediplanação durante o Eopaleozóico; **2.** um truncamento erosional pós-rifte; e **3.** erosão por correntes oceânicas que precederam o estabelecimento da Corrente Circumpolar Antártica aproximadamente ao tempo do limite Cretáceo-Terciário. Os perfis sísmicos revelam que no Paleogeno Inferior, depósitos de driftes sedimentares, com centenas de metros de espessura, foram depositados sobre o Platô. Uma quarta seqüência deposicional, ainda não perfurada é limitada na base por uma inconformidade intracretácea originada pela atividade de correntes oceânicas e, no topo, pela superfície erosional associada ao limite K/T mencionada acima. A geometria dessas unidades sedimentares é apresentada em seis mapas de isópacas e de estrutura do embasamento.

INTRODUCTION The Falkland Plateau lies within a complex physiographic region of the South Atlantic, east of southern Patagonia and the Falkland/Malvinas Islands (Fig. 1). It is an almost rectangular area about 1,200 km long from east to west and 300 km wide. It lies at a water depth of approximately 2,000 m, several kilometers shallower than the surrounding oceanic floor. Steep slopes limit the plateau on three of its sides of which the most abrupt margin is the Falkland Escarpment to the north with slopes greater than 8 and up to 45 degrees of more (Le Pichon *et al.* 1971, Lonardi & Ewing 1971). Along the eastern boundary, where the Plateau merges with the Georgia Basin, as well as on the slopes of the Falkland Trough to the south, the topographic gradient is smaller, about 1-2 degrees. The Trough is an elongate depression nearly 100 km wide that tapers off in the west separating the Falklands/Malvinas continental shelf from the Burdwood Bank. In the east, it reaches the southeastern extremity of the Maurice Ewing Bank (Barker *et al.* 1977), an elevated triangular bank which constitutes the eastern third of the Plateau and has it shallowest point in about 1,500 m of water.

During DSDP legs 36 (sites 327, 329 and 330) and 71 (sites 511 and 512) (Fig. 2), three major unconformities that we shall call UI (basement), U2 (Jurassic/Cretaceous), U4

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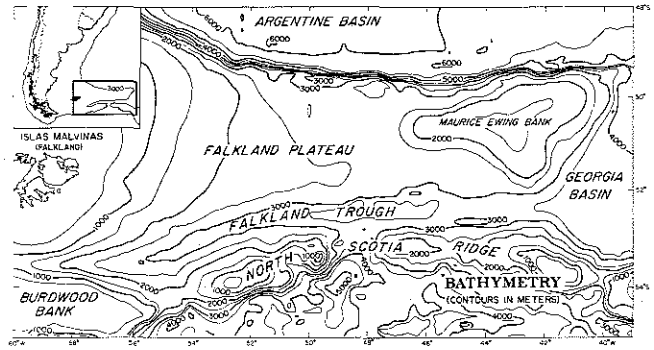


Figure 1 – Bathymetric map and general location (inset) of study area

(Cretaceous/Tertiary) were biostratigraphically dated and tied to the acoustic stratigraphy of the Plateau (Barker 1977). Together with a new mid-Cretaceous (U3) major unconformity which is not correlatable with any of the available well data, we have defined four major widespread depositional sequences (Vail *et al.* 1977) to describe the seismic stratigraphy of the Falkland Plateau. For this we have used over 14,000 km of marine seismic measurements collected since 1967 on 17 cruises (Fig. 2), as well as published DSDP results from legs 36 and 71 (Barker *et al.* 1977, Ludwig *et al.* 1983). Although most of the data are relatively low resolution single-channel reflection profiles, six regional MCS lines (Ludwig & Rabinowitz 1980) have been employed to trace reflections from their point of correlation at DSDP sites 327, 329, 330, 511, and 512 throughout most of the Plateau and regionally consistent seismic facies have been recognized and mapped.

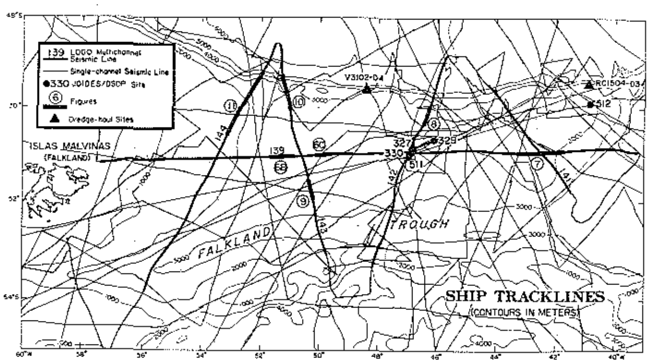


Figure 2 – Ships' tracks of cruises from which seismic and dredge-haul data where used in this study. Thin lines marking paths along which single-channel seismic data were collected, thick and numbered lines corresponding to multichannel seismic data. The thick bars locate seismic data seen in the following figures whose number is shown. Darkened circles and accompanying numbers refer to DSDP well sites. Also shown are the site where mafic rocks were dredged: RC1504-D3: gabbro; V3102-D4 olivine basalts

From results of the earliest seismic refraction experiments carried out on the Falkland Plateau (Ewing & Ewing 1959), it was concluded (Ewing *et al.* 1971) that the region consisted of a southward-tilted continental block capped by a thick, wedge-shaped body of sediments. Later work, however, revealed a deep basin, the Falkland Basin (Fig. 3), centered between the continental shelf to the west, the Maurice Ewing Bank to the east, and a basement high to the north, of which the Falkland Escarpment is the northern flank (Barker *et al.* 1977, Ludwig *et al.* 1978a, Ludwig *et al.* 1978b, Ludwig & Rabinowitz 1980, 1982, Ludwig 1983, Dingle *et al.* 1983). Rabinowitz & LaBrecque (1979) modeled the Escarpment as the continent/ocean boundary and located the Falkland Fracture Zone north of the Escarpment proper.

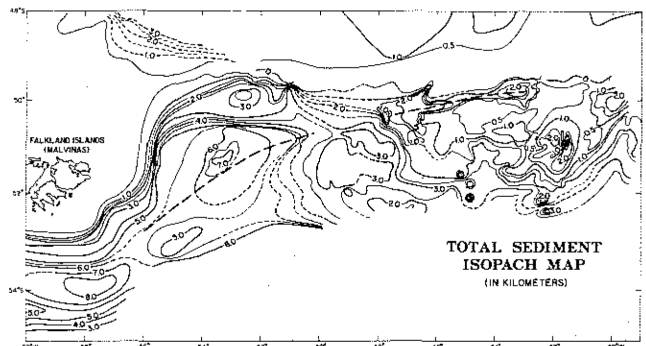


Figure 3 – Total sediment isopach map: C.I. = 0.5 km. The Falkland Basin is centered between the Falkland island, the Maurice Ewing Bank, and the northern Escarpment. Estimates of thickness for this and the following isopach maps were made using sediment velocities of Ludwig et al. *(1978b) and Ludwig (1983). In this and all similar maps that follow, contours are dashed in to indicate an interpretation. Long dashes denote the axes of some major basins.*

BASEMENT Basement on the Maurice Ewing Bank has been sampled both by drilling and dredging. At DSDP site 330 (Fig. 2) basement was encountered 550 m subbottom (Beckinsale *et al.* 1977) and found to be composed of granitic pegmatitic continental rocks of about 535 ± 66 Ma in age as derived from Rb-Sr whole-rock isochron data. Basement crops out only on the northern Escarpment and dredge-hauls at the top of the Falkland Escarpment have collected a variety of large-sized (20 cm average diameter) igneous and metamorphic rocks having such compositions as gabbro, basalt, quartzite, slate, and gneiss, the last being the most abundant. In particular, the gabbro and basalt samples have only been found on the Escarpment's edge, near basement outcrops. They were probably taken in situ and not ice-rafted (Fig. 2) otherwise they would have been found elsewhere on the Plateau.

Bank is cut obliquely in an ENE–WSW direction by a broad (50 km) and deep basin (2-4 km) (Fig. 3). Seismic structure maps and sections (Figs. 4-8) show that basement on most of

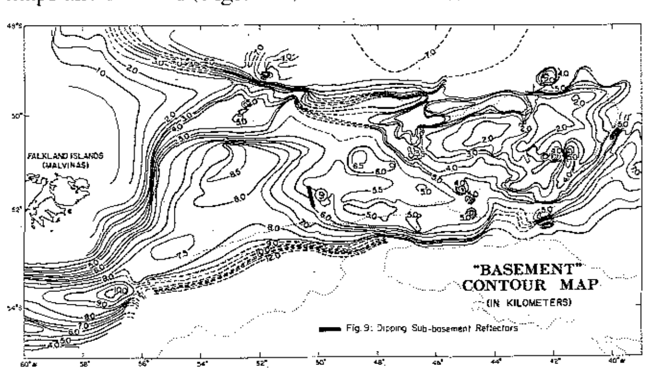
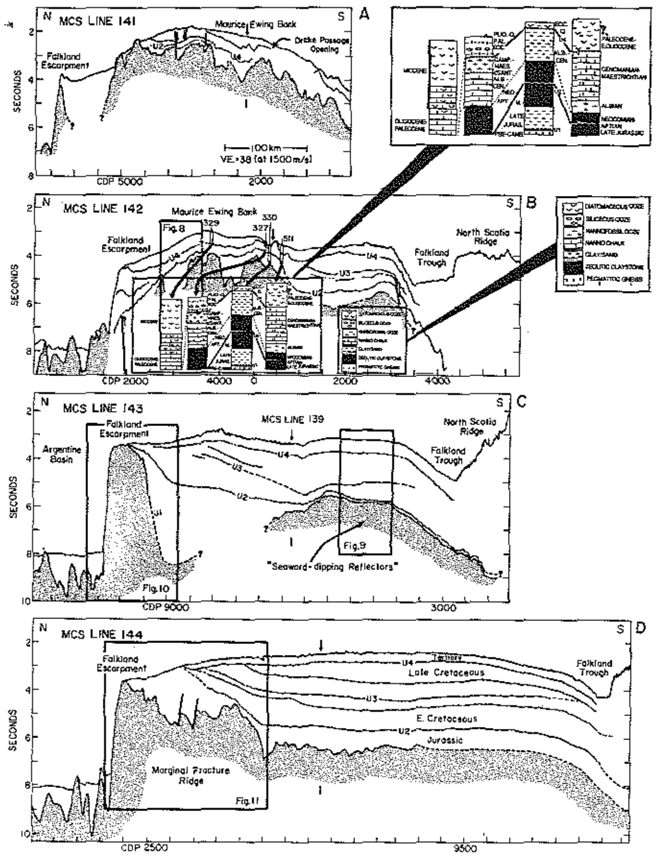


Figure 4 – Depth-to-basement map: C.I. = 0.5 km. The thick bar marks the location of dipping events in the basement. Basement is composed of gneisses and granite pegmatite at DSDP Site 330 and is Late Precambrian in age. Note the conical features to the south and southwest of the Maurice Ewing Bank which have been interpreted as volcanic edifices



Figures 5A-D – Line interpretation of multichannel seismic lines 141-144, locatable on track chart in figure 2. Boxed sections show the location of seismic profiles seen in other figures as numbered. An arrow points to the place of cross-over with Line 139 (Fig. 6a). DSDP site locations have been projected obliquely onto Line 142 and are displayed by vertical rectangles. Adapted from Ciesielski & Wise (1977) and updated using drilling results (Ludwig et al. *1983)*

the Maurice Ewing Bank is characterized by a planar horizontal reflector forming a smooth central tableland, intersected by basins that increase in size eastwardly. At the eastern end of the Bank they are oriented NE–SW and at the western end, NW–SE. In cross section, these basins are asymmetrically V-shaped, 10-20 km wide and 2-3 km deep with their steepest wall facing east. We interpret them to be half-grabens (Fig. 7). To the west they become smaller, less abundant, and more symmetric. As can be seen in the N–S section of MCS Line 142 (Fig. 8), basement geometry is very complex along the northern edge of the Maurice Ewing Bank, probably due to strike-slip faulting (Fig. 8). Basins vary in size and shape and are multiply deformed.

The top of basement throughout the Plateau has a variable acoustic character and generally, as over most of the Maurice Ewing Bank, we cannot see any reflective horizons within the basement. An exception to this exists at the eastern end of the Bank where we observe westward tilted subbasement reflectors (Fig. 7). Basement topography in the Falkland Basin is rough and irregular, and we have identified several volcanic edifices to the south and southwest of the Bank (Figs. 3, 4). They appear as small, isolated, cone-shaped bodies unbounded by faults, about 30 km wide at their base and a few kilometers high. One of them crops out at sea floor (Lonardi & Ewing 1971) southwest of the Maurice Ewing Bank. Dipping reflectors below the Falkland Basin basement appear at several locations, but are best developed on the southern slope of a local basement high (Figs. 3, 9). They are characterized by offlapping relationships, non-hyperbolic geometries and a systematic decrease in dip towards the south (Fig. 9). These characteristics have been interpreted as subaerial lava flows in areas of overthickened oceanic crust (Mutter *et al.* 1982), and could therefore be indicative of a volcanic basement for the central Falkland Basin. Their limited occurrence make such an interpretation somewhat speculative.

The Falkland Basin is confined to the north by a "marginal fracture ridge" (Le Pichon & Hayes 1971) about 50 km wide and several kilometers above the contiguous basin floors. The ridge probably existed from very early in the development of the region because only the deepest and thus oldest Jurassic sediments are in any way affected by faulting. Moreover as seen on Line 143 (Fig. 10) a very thick pile of (Middle?) Jurassic sediments onlap the ridge, showing no evidence of tectonic disturbance. The Falkland Escarpment is

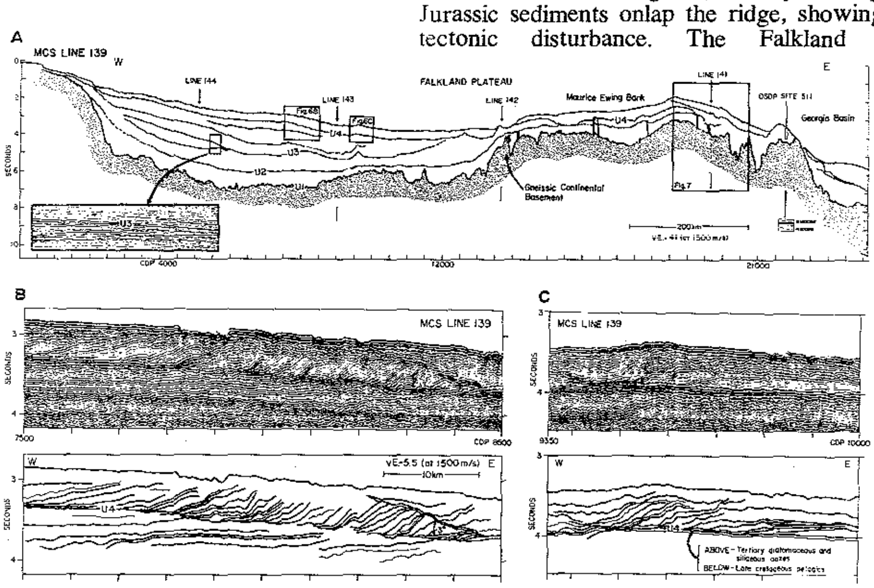


Figure 6 – **A.** *Line interpretation of multichannel seismic Line 139 showing major depositional sequences. Vertical arrows and lines point to cross-over locations with other lines as numbered. Open vertical rectangles are the DSDP well-sites projected obliquely onto this cross section. The lithological key is as in the previous figure. Boxed sections show location of seismic profiles seen in other figures as numbered;* **B.** *and* **C.** *– Highlights of migrating sediment drift seismic configuration. U4 is the regionally defined Cretaceous/Tertiary unconformity*

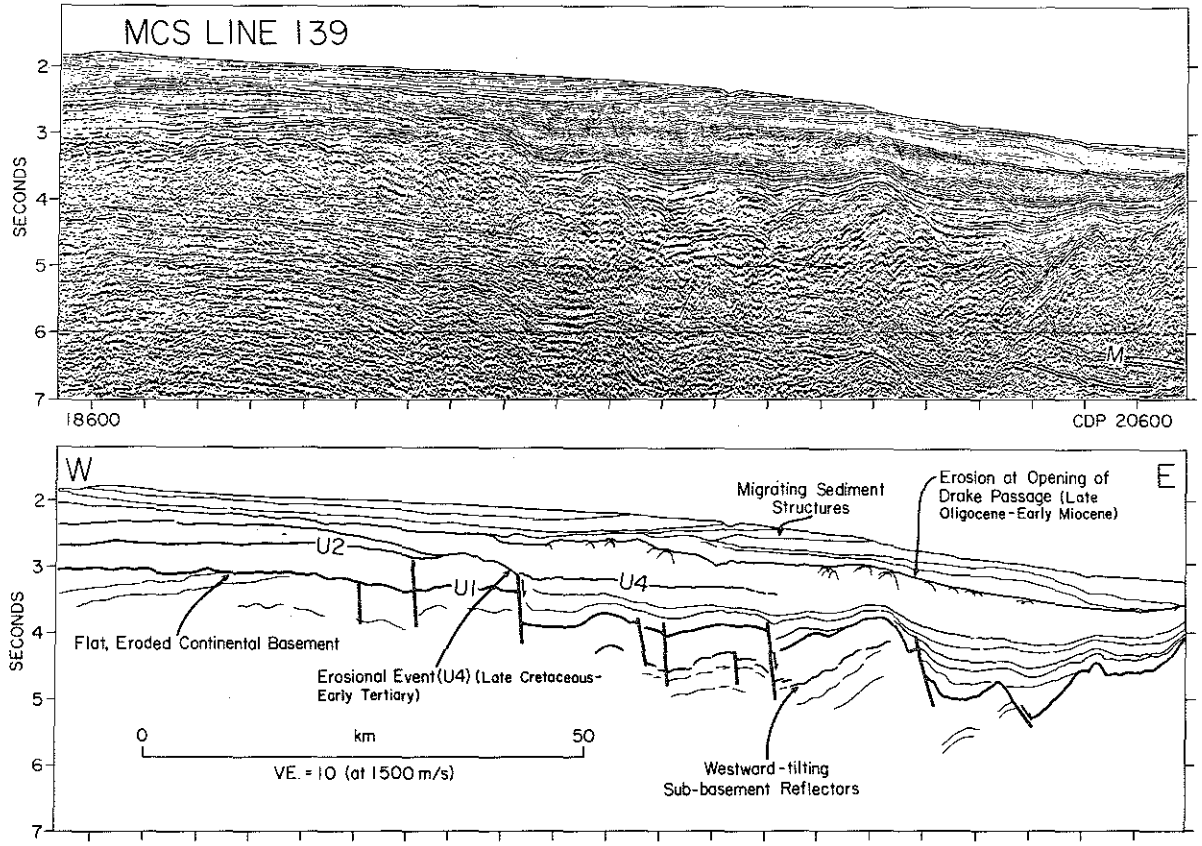


Figure 7 – Multichannel seismic profile and line-drawing interpretation from the eastern extreme of the Plateau showing: **1.** *top of basement (U1), normally faulted during rifting of the South Atlantic, and* **2.** *within the upper half of the Tertiary depositional sequence, a strong migrating sediment drift seismic configuration, probably a record of the opening of Drake Passage and the onset of strong ocean-bottom circulation. In this and all the following sections M lies on the first seafloor multiple*

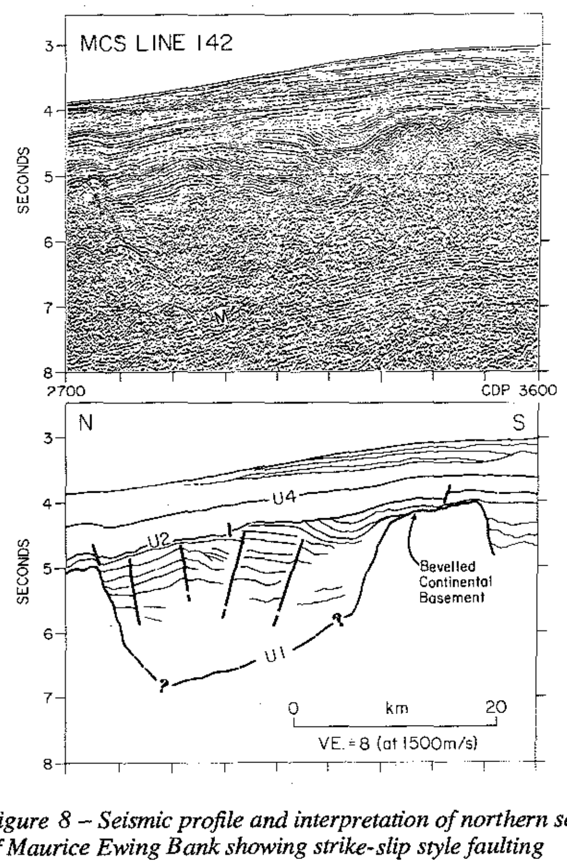


Figure 8 – Seismic profile and interpretation of northern sector of Maurice Ewing Bank showing strike-slip style faulting

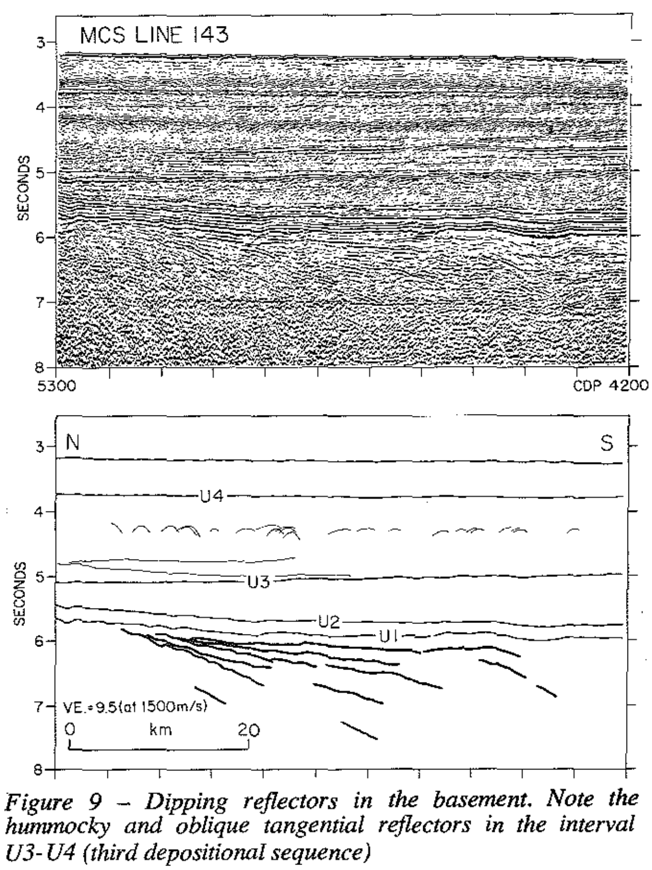


Figure 9 – Dipping reflectors in the basement. Note the hummocky and oblique tangential reflectors in the interval U3-U4 (third depositional sequence)

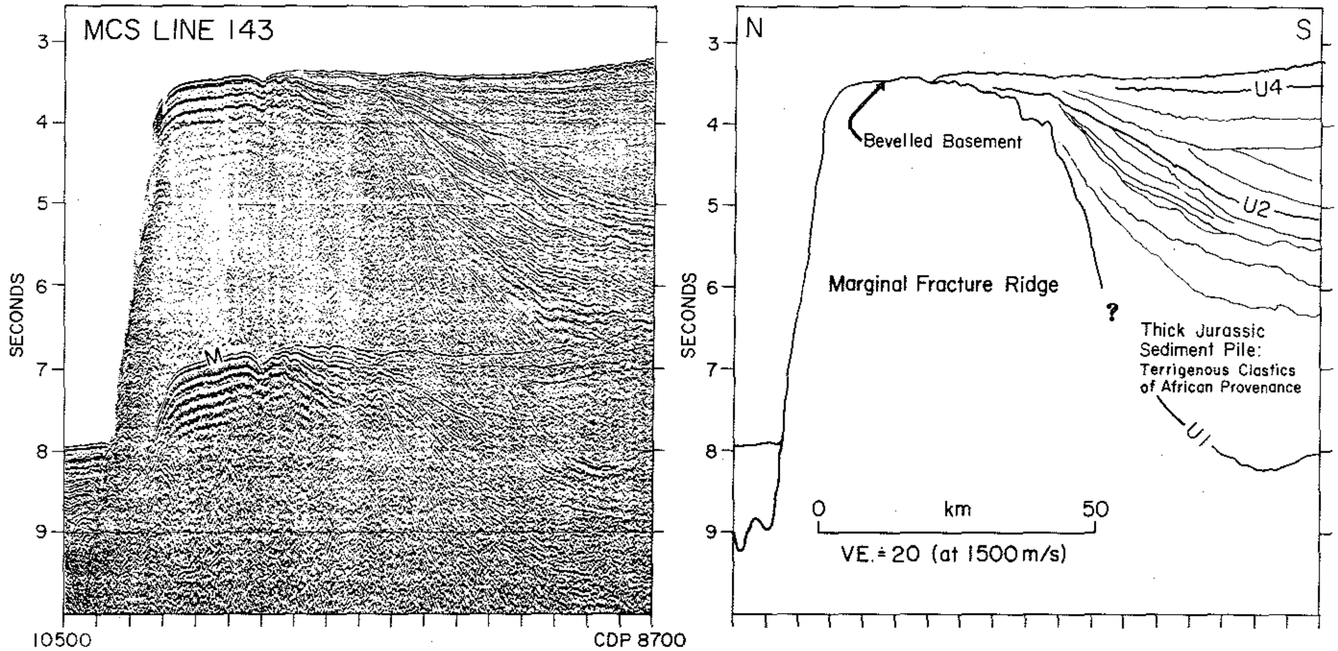


Figure 10 – Multichannel seismic profile (Line 143) and line-drawing interpretation from the northern margin of the Falkland Plateau (marginal fracture ridge). Note the narrow ridge and its bevelled top. The sediment pile that thins notably southwards and the progradational clinoform configurations suggest a northward provenance of sediment from the once adjacent African craton. The angular unconformity between U2 and U4 is not U3, but a deeper reflector marking a change in the sedimentation pattern from progradational from the north to draping. Perhaps it marks the end of a terrestrial sediment source such as when the African Plate cleared this point.

the northern exposed face of this ridge. In places, as in the cross-strike section of Line 144 (Fig. 11), we can distinguish three regions: **1.** the marginal ridge; **2.** a central depression with half grabens whose steepest sides dip to the north; and **3.** a more planar basement high (Fig. 11). Dredged basalts and gabbros suggest some unknown amount of extrusive volcanic construction on the Escarpment and/or intense vertical block movement such as recorded at the equatorial fracture zones (Bonatti *et al.* 1977).

DEPOSITIONAL SEQUENCES AND DSDP DRILL SITES Continuous strong parallel reflectors typify the acoustic character of the first depositional sequence which onlaps basement (U1), especially in the Falkland Basin. Within some asymmetric grabens on the Maurice Ewing Bank, reflections are chaotic at the fault edge and converge towards the opposite margins, probably a result of syntectonic sedimentation accompanied by slumping. DSDP results (sites 330, 511) show that the top boundary, paraconformity (U2), spans a period of about 30 Ma from the Portlandian to the Late Neocomian and showing the same black shales above and below.

Drilling results at Site 330 show that Jurassic sediments lie unconformably on the basement (Figs. 5a-d). They exhibit a fining-upwards tendency within the first meters, interpreted as the effect of the gradual isolation from terrestrial influence. The exclusively terrestrial component of the Jurassic is extremely thin (Thompson 1977). The drilling site was positioned over the shoulder of a basement deep (Fig. 5b); more representative and perhaps thicker terrestrial units might occur toward local basin depocenters. For the remainder of the unit, black undisturbed laminated shales were drilled. They have no paleodepth indicators and show only that a steady and high sedimentation took place under anoxic bottom-water conditions. However, through this indicates restricted ocean-bottom circulation on the Maurice Ewing Bank, we observe progradational acoustic patterns at

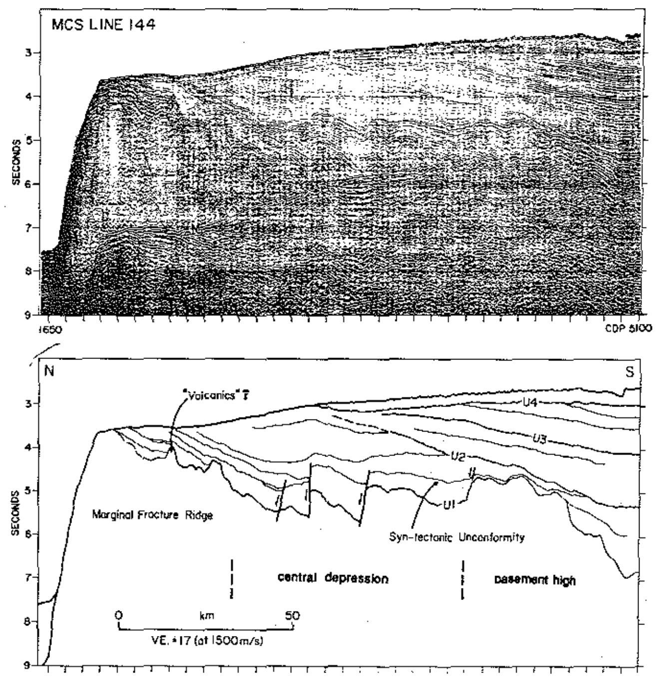


Figure 11 – Multichannel seismic profile (Line 144) and line-drawing interpretation from the northern margin of the Falkland Plateau (marginal fracture ridge). The major features are: **1.** *the half-graben style basement faulting involving overlying sediments in a transtensional regime;* **2.** *southward dipping sediments; and* **3.** *multiple unconformable stratigraphic relationships*

the edges of the Falkland Basin. Along Line 143 (Fig. 10), the sequence thickens northwards from a few hundred meters in the center of the Plateau, to 2,250 m just south of the Escarpment. It pinches out over the marginal ridge concomitantly with a change in the character of U2 from a paraconformity to an angular discordance. In figure 10, the sediments below U2 do not have the aspect of hemipelagic drape but consist of parallel onlapping reflectors that are thicker towards the elevated Escarpment. In order to explain the large sediment thicknesses even at the highest observed pelagic sedimentation rates, terrestrial sediment input is needed, derived most likely from the then-adjacent African Plate (Thompson 1977). Thus, we interpret the reflection configuration as indicating terrigenous slope deposits. Sediment thickness in the first sequence varies with depth to basement (Fig. 12), the greastest occurring in the western half of the Falkland Basin and the smallest in the central northeast sector. These two areas are completely surrounded by small and even negligible sediment thicknesses (less than 250 m in the south and on the Maurice Ewing Bank). The central basement high in the Falkland Basin (Fig. 5c) is thinly covered by the first sequence. Sedimentation was more probably pelagic in nature since the surrounding acoustic configurations do not indicate that this local high was a subaerially eroding sediment source, or that terrigenous sediments prograded in from the north. In general, it is suggested that close to the Escarpment and source, the first sequence has a complex basin-fill form, whereas everywhere else it is more draping in character.

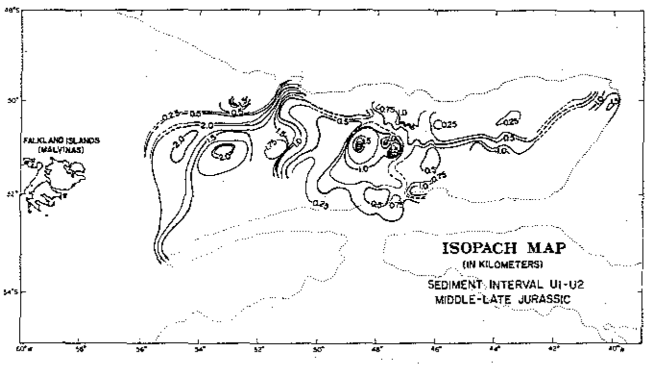


Figure 12 – Isopach map of Jurassic depositional sequence located between unconformities U1 (on basement) and U2. C.I. = 0.5 km. Dotted line represents the 3,000 m isobath for reference

In general, the second depositional sequence (interval U2-U3) has a seismic facies consisting of laterally incoherent parallel reflectors. It thickens towards the west and eastern ends of the Falkland Basin (Fig. 13), near the Maurice Ewing Bank, becoming internally chaotic in character except for a few reflectors that onlap the basal unconformity U2. Complex seismic configurations near the Escarpment (Fig. 10) show angular discordances within the unit and an apparent shift of the depocenter southwards. The greater part of this unit lies in the Falkland Basin, bounded at its top by unconformity U3. U3 (Mid-Cretaceous) was defined because it erosionally truncates several lens-shaped bodies, one of which is a regionally extensive unit that can be seen in figure 6a. However, U3 is not clearly correlatable with any of the DSDP well data. Lithologies change drastically at the Aptian/Albian boundary from sapropelic claystone below to zeolite-rich nanno clay above, marking the beginning of open ocean circulation when Africa cleared the Falkland Plateau (Barker *et al.* 1977).

The third depositional sequence (interval U3-U4) is

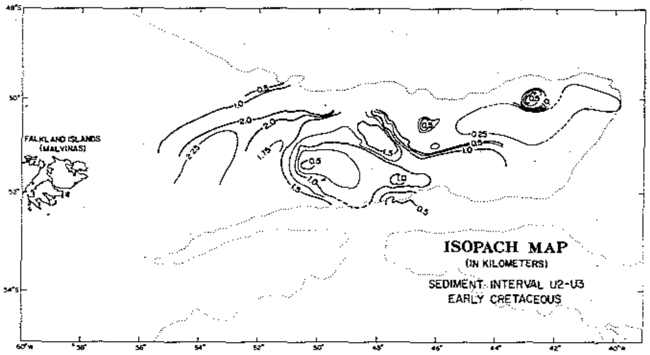


Figure 13 – Isopach map of Early Cretaceous depositional sequence located between unconformities U2 and U3. C.I. = 0.5 km. Dotted line represents the 3,000 m isobath for reference

restricted to only the central Basin and is unsampled by drilling. Everywhere else on the Plateau its top appears erosionally truncated by U4 (Cretaceous/Tertiary). The isopachs for this unit are concentric about the depocenter (Fig. 14) located slightly east of the point of maximum total sediment thickness for the Plateau. Hummocky and oblique tangential reflectors are abundant throughout (Figs. 6b, 6c, 9). These seismic patterns probably resulted from ocean current activity since the available well data implies that most of the sediment was pelagic. Over most of the remaining area, the reflectors are flat and parallel. It is difficult to see the complete internal geometry of these units because they are erosionally truncated by U4. Depositional unit three cannot be traced onto the Maurice Ewing Bank and a plot of the velocity vs. one-way traveltime (Ludwig *et al.* 1978b, Ludwig 1983) show a larger velocity gradient in the sediments of the Maurice Ewing Bank (1.98 km/s^2) than in the Falkland Basin (1.49 km/s^2), even though the average thickness of the sediment cover is half as much. This indicates that there may have been extensive removal of sediments at the end of the Cretaceous (U4). The state of diagenesis in the black shales of the first Depositional Sequence also suggests a deeper burial as well as a higher thermal gradient than present at the well site (330) (Comer & Littlejohn 1977).

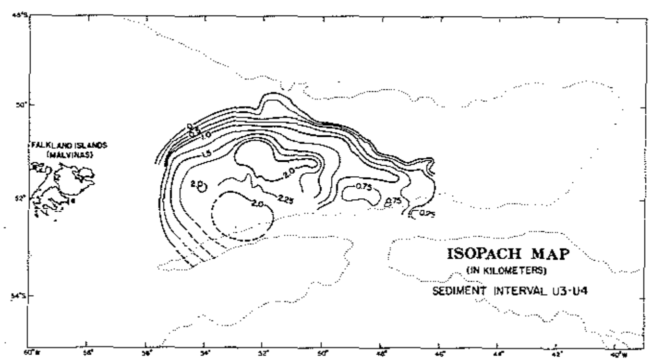


Figure 14 – Isopach map of Late Cretaceous depositional sequence located between unconformities U3 and U4. C.I. = 0.25 km. Dotted line represents the 3,000 m isobath for reference

Throughout the Falkland Plateau, based on two-dimensional seismic sections, Sequence Four forms a sheet several hundred meters thick that progressively thins towards the Falkland Escarpment (Fig. 15). It is delimited by a coherent high amplitude basal reflector and sea floor. The sequence can be further subdivided into tabular units with overlapping tapered ends. On E–W lines, the internal seismic reflection configuration changes from oblique parallel and tangential (about 3-6° of maximum apparent dip) at the edges of each tabular unit, to very low angle oblique configuration patterns towards the center (Fig. 6b, 6c). Along most N–S sections, the configuration is oblique parallel, almost horizontal. The base has a two-fold nature: commonly it is an horizontal flat reflector, but in a few places it can be hummocky and discontinuous (Fig. 7).

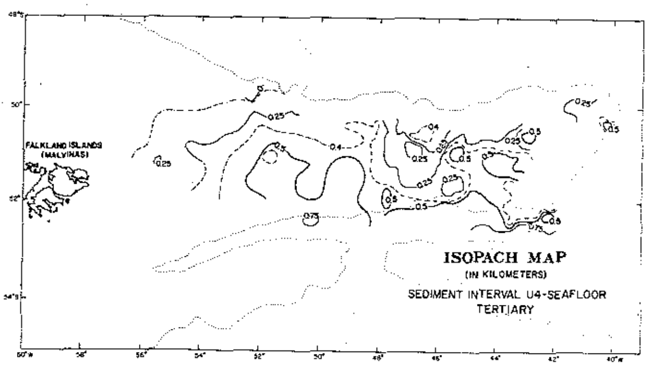


Figure 15 – Isopach map of Tertiary depositional sequence located between unconformities U4 and sea floor. C.I. = 0.25 km. Dotted line represents the 3,000 m isobath for reference

Depositional Sequence Four's lower bounding unconformity (U4) erosionally truncates all of the underlying sequences on a regional scale (Figs. 5a-d, 6a). U4, which extends throughout the Central Basin and Maurice Ewing Bank, marks a 10 million year hiatus (Fig. 16) of Late Cretaceous/Early Tertiary age. Where drilled, this Tertiary sequence consists mainly of diatomaceous nannofossil, calcareous, and zeolitic oozes (Barker *et al.* 1977, Ludwig *et al.* 1983).

A reasonable distinction can be made between the seismic facies character of the fourth depositional sequence in the Falkland Basin and on the Maurice Ewing Bank. On the Maurice Ewing Bank the sequence thickness is more variable (0.25-0.5 km) and consists mainly of wavy discontinuous and very low angle oblique seismic reflection configurations. Within the upper half of the sequence there is a wavy erosional truncation that we have not been able to correlate with confidence between MCS lines. This horizon can be tied to a Miocene/Oligocene unconformity (Barker *et al.* 1977, Ciesielski & Wise 1977). The overlying subunit contains clear clinoform features and much more laterally continuous reflectors than the rest of the sequence (Fig. 7). Adjacent seismic lines exhibit comparable features and we assume that they represent the same event.

Sequence Four displays the seismic reflection configuration of a large field of drift deposits. Similar geometric arrangements have been described for deep ocean current-controlled deposits of varying scales. Mountain & Tucholke (1985) propose that seismic wave facies on the U.S. Atlantic continental rise comparable in size and extent to those of the Falkland Sequence Four are created through differential sediment deposition under the influence of a major unidirectional current, such as the western boundary undercurrent. They cite the core of the Blake Outer Ridge as one of several examples. Gonthier *et al.* (1984) have also suggested that smaller-scale drift deposits prograde obliquely to the direction of the main current. For both models the long axis of the sediment body is parallel to the major current flow but the internal dip of beds is oblique to it. After examining the unit along differently oriented lines, it seems that the structures are steepest and best developed along E–W lines.

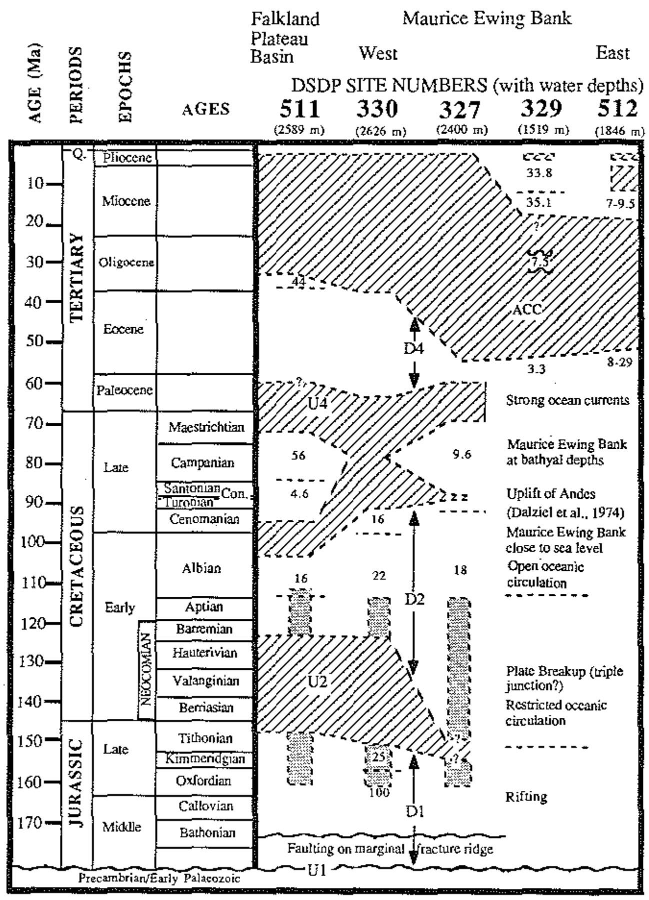


Figure 16 – Correlation of the different unconformities from DSDP Legs 36 and 71 (see References). *Time gaps in the sedimentation are hatched; numbers are observed sedimentation rates in m/Ma, and the shaded bars show the time span during which sapropelic claystone was deposited. At Site 327, the extent of the claystone is interpreted. We have indicated the corresponding seismic units (U-unconformity, D-depositional sequence) and a few key observations and interpretations for different times (Palmer 1983)*

Thus we would conclude that the paleocurrents moved obliquely to the E–W direction.

There is controversy as to whether the Antarctic Circumpolar Current became fully established in the early Oligocene (LaBrecque & Rabinowitz 1977) or in the late Oligocene (Barker & Burrell 1977, 1982). It is thought to be responsible for a sedimentary hiatus at DSDP Site 329 (Fig. 5b). Our data suggest that U4, being deeper in the seismic records and hence older than the corresponding reflector, is a much more widespread and easily correlatable horizon over the whole Plateau. Because of its erosive nature, we suggest that it formed during a period of strong current activity, not necessarily as a percursor to the Antarctic Circumpolar Current on the Plateau, but maybe as one of many similar events as there are many smaller-scale unconformities in the Cretaceous. Such a notable unconformity might be registered in other regions throughout the Atlantic as well.

FAULTING Basement-involved faulting affects overlying sediments of Jurassic to Early Tertiary age and major normal faulting (*i.e.*, large offset) ends below U2 (Neocomian), affecting mainly the lower half of the first depositional sequence as highlighted by a syntectonic unconformity (Fig. 11).

In plan view, the basement of the Maurice Ewing Bank has an irregular polygonal shape outlined by steep slopes whose extensions lead across areas of normal fault-tilted blocks. We believe that the linear edges of the basement have been created by faulting during extension. If so, extension was complex in orientation: the eastern edge that enters the Georgia Basin runs NE–SW (approximately parallel to the oldest ocean magmatic anomalies M10-M11), and the western edge that leads into the Falkland Basin runs NW–SE. Most probably the eastern edge was developed during rifting away from Africa, whereas the western trend is related to another direction of extension. Since the oldest known sediments are Middle Jurassic in age, and most of the obvious faulting occurs in the lower parts of the first depositional sequence, rifting may have been taking place since at least the Middle Jurassic. Simultaneous spreading in different directions occurs at triple junctions. Some authors argue for a triple junction south of the Plateau between Africa, Antarctica, and South America, implying that the conjugate margin to the southern flank of the Plateau (in the Weddell Sea, off Antarctica) did not move away until M10 time (Martin & Hartnady 1986). From the model of LaBrecque & Barker (1981), Weddell Sea anomalies may be as old as M29. More recent work, using aeromagnetics (LaBrecque 1987) confirms a Jurassic age, at least for the Weddell Basin. Recent independent paleomagnetic results (Grunow *et al.* 1987) show, however, that the main opening of the Weddell Sea occurred in the Early Cretaceous. We have only noted evidence for volcanic activity in the basement of the central Falkland Plateau which is at least Middle Jurassic in age since that is the age of the oldest sediments. This age is in accordance with a formation of the Weddell Basin in the Jurassic (LaBrecque 1987).

The northern margin of the Maurice Ewing Bank is markedly affected by normal and reverse vertical faults (Fig. 5b, Line 142) that are accompanied by folding (Fig. 8) below U2. E–W sections show fault-tilted grabens, whereas N–S sections on the Maurice Ewing Bank show basins which are unrepetitive and unsystematic in shape. Together with the geological setting close to a fracture zone, we attribute the deformation to movement along the transform fault during rifting and early seafloor spreading in the South Atlantic. Apparently relatively little faulting is present in the central Falkland Basin.

DISCUSSION

Our synthesis of seismic reflection data, together with the results of earlier investigations, show clearly that sediment thickness changes markedly throughout the Plateau. In particular, the Falkland Basin is a major depocenter containing up to 7 km of post Middle Jurassic strata adjacent to which, on the Maurice Ewing Bank, sediments thin to as little as 0.5 km. Total basement depths vary from 2.0 to 8.5 km. Very different subsidence histories for the Basin and adjacent Maurice Ewing Bank are clearly implied. We have little data upon which to base a truly quantitative study of the Plateau's subsidence history and the implications it might have for crustal deformation. However, we can offer the following observations and suggestions.

The Maurice Ewing Bank apparently experienced an unusual subsidence history. Although spreading was initiated in the South Atlantic in the Early Cretaceous, around the time of magnetic lineations M10-M11 (Larson & Ladd 1973), Sliter (1977) has shown that the Maurice Ewing Bank was probably not deeper than 400 m in the late Albian based on paleoecological foraminiferal assemblages. Thus much of the subsidence to its present basement depth of around 2 km was achieved during the Late Cretaceous (Fig. 16). If we assume that this subsidence is dominantly thermal, an explanation for this may be provided by the presence of the ridge itself. Since the northern boundary of the Falkland Plateau is a transform margin, the mid-ocean ridge would have remained adjacent to the Plateau until it had cleared its easternmost limit. LaBrecque & Hayes (1979) show that this occurred around anomaly 34 time (Early Campanian), during the period of greatest subsidence on the Maurice Ewing Bank. We therefore believe that subsidence of the Maurice Ewing Bank was "delayed" until the thermal effect of the ridge had begun to retreat away from the Plateau. It is left to quantify this effect and consider as well whether a mechanical coupling between the African and the Plateau could have sustained the Bank elevated for the long period of time.

At present, paleoreconstructions position the eastern end of the Falkland Plateau in predrift times against the southern face of the Tugela Cone (Martin *et al.* 1981). The fit is very good and requires that any significant seafloor spreading or stretching in the Falkland Basin occurred before the beginning of drifting. We have obtained relatively small (140-160%) average crustal extension factors across the Plateau by balancing simple estimates of present-day crustal cross sections with standard continental crustal blocks at sea level (Ludwig *et al.* 1965) 30 km thick. Along a section at 51°S the apparent extension, assuming it to be all in an E–W direction, is about 160%, or 450 km, though locally it can be much greater.

The nature of the crust flooring the Falkland Basin has not been determined by previous studies, although Ewing *et al.* (1971) and Ludwig & Rabinowitz (1980) infer that the crust must be unusually thin. The great depth of the basement (up to 8.5 km) in itself implies a relatively thin crust. Simple considerations of mass balance against a standard 30 km continental crustal column suggests that the crust must be around 12 km thick. Furthermore, by making a simple isostatic unloading of the sediment cover, we deduce a basement depth about 5.0 km which can be used to determine an extension factor of about 280% (Le Pichon & Sibuet 1981). Assuming an initial 30 km crustal thickness, a present thickness of around 11 km is implied.

A crustal thickness of 11-12 km beneath the Falkland Basin is consistent with either a highly thinned continental section or a somewhat thicker-than-normal oceanic section. Evidence for volcanism in the form of seamounts and dipping layers within the basement (Fig. 9) suggests that, if stretching of continental crust was involved, it was accompanied by significant melt generation. Foucher *et al.* (1982) have shown that stretching factors greater than 3 (*i.e.*, 300% extension) lead to the formation of a melt-derived magmatic layer equivalent in thickness to that of normal oceanic crust, *i.e.*, beyond factors of 3, oceanic crustal generation is possible. Although our data base only allows for a fairly rough estimate of stretching factors, it seems that stretching of the Falkland Basin basement proceeded to a point where oceanic crustal accretion had either begun or was about to begin. We cannot rule out the possibility that oceanic crust underlies the basin.

CONCLUSIONS

The Falkland Plateau was subjected to extension during the Middle Jurassic to Early Cretaceous. The Falkland Basin extended in a direction oblique to that of the Georgia Basin and is possibly floored in places by highly thinned continental crust invaded by volcanics or possibly a thick oceanic crust. Along the northern margin of the Plateau, compression and extension as a result of strike-slip movement along the former transform fault deformed basement and sediments. The marginal fracture ridge was created very early in the history of the Plateau and from dredge-haul data appears to be composed of continental-type rocks as well as "oceanic-type" basalts. We speculate that thermal uplift may have been induced from the input of heat from an oceanic ridge passing along the Fracture Zone (Fig. 17). If so, it may

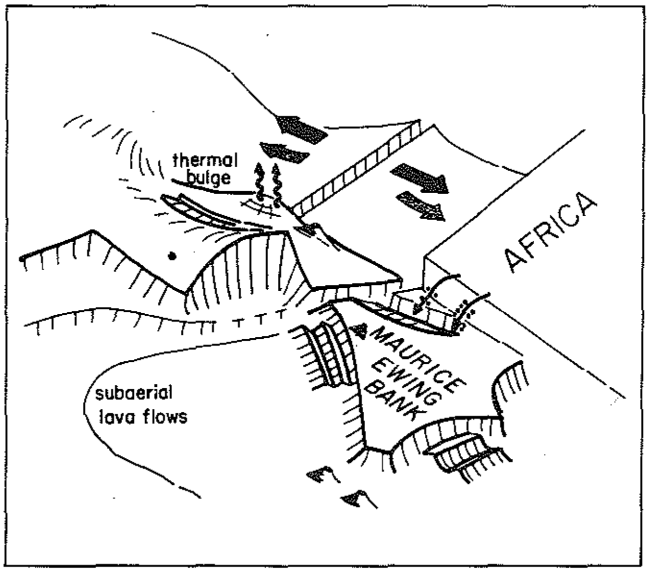


Figure 17 – Schematic block diagram of the Falkland Plateau basement (without sediment cover) in the Early Cretaceous based on discussion in text. Hachures represent sloping surfaces. During that time, Africa slid past the Maurice Ewing Bank, shedding sediments into transtensionally derived basins. We propose that the oceanic ridge to the north thermally induced an uplift on the fracture ridge. A protracted extensional event lasting from the Middle Jurassic through to the Early Cretaceous was responsible for the fault-tilted blocks, Volcanism on the Plateau could be at least Middle Jurassic or older. The black triangle marks the approximate location of DSDP sites 329, 330, and 511

in part account for the thermal maturity of the black shales of the first depositional sequence.

U2, a major Jurassic/Cretaceous unconformity, marks the end of important tectonic activity on the Plateau. The large thickness of the first depositional sequence adjacent to the Fracture Ridge requires a terrigenous input. Above U2, the Cretaceous and Tertiary sequences show marked signs of deep ocean circulation. Before the onset of the Antarctic Circumpolar Current, a giant field of migrating drift deposits was established on the Plateau. The Antarctic Circumpolar Current is most clearly registered in the seismics of the Maurice Ewing Bank. Many of our arguments could be confirmed by: **1.** drilling close to the Escarpment to study the possible effects of the passing of the hot ocean ridge, and **2.** modeling of the gravitational and magnetic field anomalies over the Falkland Basin to constrain the nature of the crust.

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...a pomposa expressão 'compra de tecnologia', tão empregada para caracterizar a compra de instruções pelas indústrias nacionais, será aqui substituída pela expressão correta 'compra de receita'. Outro nome apropriado seria 'aluguel de tecnologia'... Essa classificação de 'aluguel' em lugar de 'compra' não é puramente acadêmica, como poderia parecer aos incautos, mas de extrema importância, pois dela depende a clara compreensão do fenômeno da espoliação dos países pobres no que diz respeito à tecnologia.

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