THE LEMAY GROUP ACCRETIONARY COMPLEX, ANTARCTICA

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Summary

The LeMay Group of Alexander Island on the western side of the Antarctic Peninsula is an unusually wide accretionary complex compared to the remainder of the palaeo-Pacific margin of Antarctica. The exposed part of the complex is up to 300 kms wide and is preserved in an embayment of the arcuate Mesozoic magmatic arc. It is comprised of deformed trench-fill turbidites, trench slope sequences, and allochthonous slivers of ocean-floor and ocean island igneous and sedimentary rocks. The age of the complex is constrained by the presence of an Early Jurassic ammonite from accreted tuffs within an ocean island sequence, and by Late Jurassic to Early Cretaceous and mid-Cretaceous radiolarian from accreted cherts. All of the ages are from allochthonous units which place maxima on the ages of accretion in those parts of the prism where they are exposed. The ages show a pattern of younging towards the margin consistent with an accretionary prism model. On the eastern side, the complex is unconformably overlain and in faulted contact with a forearc basin sequence which places a minimum Middle Jurassic age on this part of the prism. The complex may have developed by the accumulation of docked exotic terranes in a preexisting embayment along the palaeo-Pacific margin, or alternatively by long-lived subduction and accretion along this segment of the margin. In the latter case, subsequent oroclinal bending of the magmatic arc may account for the unusually wide complex now preserved in the arcuate embayment of the margin.

Introduction

The Mesozoic geology of the Antarctic Peninsula has traditionally been interpreted in terms of a complete Andean-type arc-trench system (Storey and Garrett 1985). Subduction is interpreted to have been active both before and after partial separation of the Antarctic Peninsula from Gondwana by seafloor spreading in the Weddell Sea. The main tectonic elements are accretion-subduction complexes on the western Pacific margin of the peninsula, a magmatic arc, represented by the Antarctic Peninsula batholith with a long record from 240 to 10 Ma (for review see Leat et al. 1995) and thick back-arc and retro-arc basin sequences on the eastern, Weddell Sea side. However, in the geological record, complete arc trench systems are unusual and Vaughan and Storey (in press), based on the discovery of a major fault zone in the magmatic arc, have divided the peninsula into geological domains (Fig. 1) and suggest that two and possibly three separate terranes collided resulting in a late Jurassic-early Cretaceous orogeny referred to as the Palmer Land orogeny. The most extensive and most well-known accretionary complex rocks, the LeMay Group, are exposed on Alexander Island on the west (forearc side) of the long-lived magmatic arc, the roots of which are now exposed on the Antarctic Peninsula. The accretionary prism is unconformably overlain by a thick forearc basin sequence, the Fossil Bluff Group. Eastward subduction of oceanic crust beneath the peninsula occurred from at least the Triassic to Tertiary times, and may have started as early as the mid-Palaeozoic (Milne and Millar 1991). Subduction ceased due to a series of ridge crest-trench collisions (Barker 1982) the age of which decreased progressively northwards along the peninsula, occurring off southern Alexander Island between 53.5±1 and 45±3 Ma, and off northern Alexander Island at 32±3 Ma. Plate convergence is still continuing off the South Shetland Islands and South Scotia Ridge.

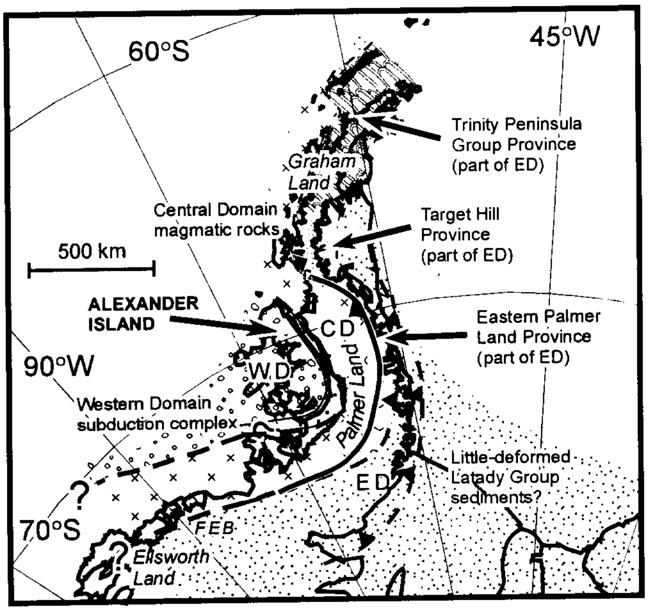

Figure 1. Terrane map of the Antarctic Peninsula (Vaughan and Storey in press). WD, Western domain; CD, Central domain; ED, Eastern Domain.

LeMay Group

Although the LeMay Group is dominated by deformed arkosic sedimentary rocks, other facies associations have also been recognised. Tranter (1991) recognised four facies associations in the central part of the LeMay Group and these have been mapped over the rest of the group (Fig. 2). Age equivalence is not implied.

Conglomerate-sandstone-mudstone association. Large thicknesses of this facies association crop out along the eastern flanks of the LeMay Range. Three facies have been recognised. A conglomerate-sandstone facies contains polymict, polymodal conglomerates interbedded with plane-laminated, normally graded sandstones forming beds up to 10 m thick. The facies is interpreted as high-density sediment gravity flow deposits. A sandstone-siltstone-mudstone facies consists of packets of locally graded laterally continuous sandstone beds passing upwards into thin repetitions of siltstone and cleaved mudstone. The facies is interpreted as the deposits of low density turbidity currents. Facies 1 and 2 form broadly fining upward sequences. A pebbly mudstone facies is volumetrically insignificant within this association. The association most likely formed in a trench slope basin environment within the prism.

Sandstone-mudstone association. The association consists of a single facies of thin- to medium-bedded sandstones and mudstones with some thicker sandstone beds and rare conglomerates. Siltstones are almost totally absent. Much of the sequence is structureless but planar, cross and convolute laminations were observed. Although good turbidite sequences were not recognised, the sedimentary structures are consistent with deposition from sand-laden erosive currents and the rocks probably represent thin-bedded turbidites deposited in a trench slope basin or as a trench fill deposit.

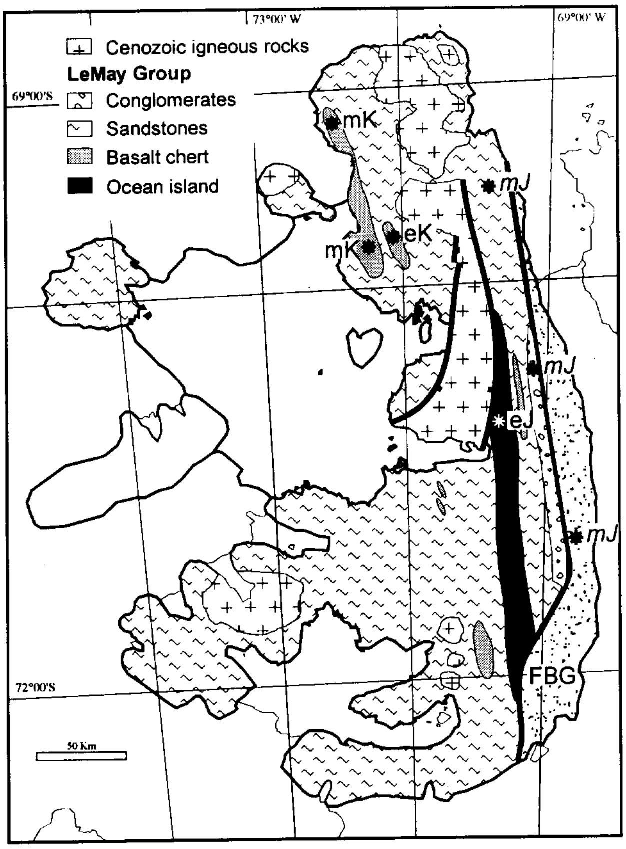

Figure 2. Geological map of Alexander Island showing facies associations in the LeMay Group together with the overlying Fossil Bluff Group (FBG) and Cenozoic igneous rocks. eJ (Early Jurassic), eK (Early Cretaceous), mK (mid Cretaceous) show the age of ocean floor rocks accreted within the prism, and mJ (Middle Jurassic) shows the age of trench slope/fore-arc basin deposits.

Ocean-floor basalt-chert association. Narrow discontinuous strips of basaltic lava and interbedded red and green radiolarian cherts, siltstones and mudstones are present within the LeMay Group. The lavas are pillowed, sheet-like and massive and may form units up to 50 m thick. Geochemical analysis show that the basalts are predominantly N-type MORB representing fragments of normal ocean floor material accreted to the margin during subduction (Doubleday et al. 1994). Enriched MORB's and tholeiitic OIB's have also been sampled indicating fragments of ocean island basalt within this association. The sedimentary units are up to 40 m thick although isoclinal folding has commonly thickened the sequence. Radiolaria are generally too recrystallized to allow accurate identification and dating although some exceptions have been reported (see below) and provide the most reliable age constraints for the LeMay Group. The identified radiolarian assemblages have Tethyan affinities which suggest that these cherts and associated basalts are far-travelled slices of the Phoenix plate (Holdsworth and Nell 1992).

Ocean-island basalt and tuff association. A distinctive sequence of pillowed and massive basic lavas together with tuffaceous sedimentary rocks form the Lully Fooothills Formation and form a distinctive linear outcrop along the central spine of Alexander Island (Fig. 2). The pillow lavas form units up to 30 m thick and are generally vesicular. Beds of hyaloclastite breccia, up to 10 m thick occur between pillowed units. Locally derived lithic and vitric tuffs indicate shallow water and subaerial volcanism. Fossils collected from the tuffs in the northern part of the formation include a diagnostic ammonite of Sinemurian (Early Jurassic age; Thomson and Tranter 1986). The lavas are geochemically varied consisting of basalts with N-MORB, E-MORB and tholeiitic OIB characteristics (Holdsworth and Nell 1992). The rock association is interpreted to represent a very large seamount or ocean island that collided with the prism during its development. The ocean island is bordered on its western side by a melange zone.

Deformation history. The LeMay Group is complexly deformed by dominantly westward- (oceanward-) directed thrusting. Structural relief introduced by later faulting reveal a wide range of structural styles and metamorphic grades representing different levels within the progressively deforming underplated units. Deformation ranges from thrust-related stratal disruption of poorly lithified clastic sediment, achieved by independent particulate flow and cataclasis, through solution dominated processes in clastic and silicious rocks, to the development of pervasive cleavage fabrics at greenschist and transitional blueschist facies, with local crystal-plastic deformation. Later deformation (crenulation fabrics and isolated zones of folding) is of uncertain origin but probably resulted form further accretionary adjustments within the underplated units. The deepest levels may have been partially exhumed by syn-accretionary backthrusting or by transpression within a strike parallel zone related to oblique convergence. Microstructural evidence reveals the importance of fluids in controlling deformation.

The LeMay Group contains several belts of melange, one of which incorporates both oceanic and trench-fill material. It evolved by many different mechanisms: dispersed independent particulate flow and limited cataclasis at shallow levels; and diffusive mass transfer and limited crystal plastic processes at deeper levels. Fluid pressures may have risen due to the subduction of young hot oceanic crust which probably affected the structural evolution of the prism.

Age of the LeMay Group. The age of the LeMay Group is poorly constrained. Age-indicative fossils recovered from the accretionary complex include: an early Jurassic ammonite from sediments overlying and within the accreted ocean island (Lully Foothills Formation; Thomson and Tranter 1986); Late Jurassic to early Cretaceous radiolaria from accreted oceanic cherts in the western part (Sullivan Glacier area) of northern Alexander Island (Holdsworth and Nell 1992); and mid Cretaceous radiolarian from similarly accreted cherts in the Havre Mountains and Debussy Heights area of northern Alexander Island. All of these are allochthonous units and they only place maxima on the age of accretion in those parts of the prism where they occur, but it is noticeable that they show a pattern of younging towards the margin. They also indicate that accretion in the outboard parts of the prism was younger than mid Cretaceous in age. In fact Holdsworth and Nell (1992) calculated the age of accretion from plate tectonic models as 95 Ma for the Jurassic-Cretaceous samples and 86 Ma for the later samples assuming that the radiolarian age was also the age of the enclosing ocean-floor lavas. A further age constraint comes from the fact that deformed rocks of the LeMay Group on its eastern margin (ie furthest from the trench) are unconformably overlain and in faulted contact with the Fossil Bluff Group on the eastern side of the island placing a minimum age of pre-Mid-Jurassic on the parts of the accretionary complex underlying the Fossil Bluff Group.

Zircon and apatite fission track data from he LeMay Group accretionary complex and from the overlying Fossil Bluff Group record a common regional Cretaceous and Cenozoic thermal and denudational history (Storey et al. 1996). With the exception of zircon crystals closest to the trench, the apatite and zircon ages central ages are substantially less than known, and inferred stratigraphic ages. Thermal modelling of the data indicate cooling from maximum palaeotemperatures in the range 180-350°C at c. 100 Ma. A younger period of accelerated cooling occurred between 40 and 35 Ma with final cooling to surface temperatures taking place at reduced rates through the Tertiary. The start of cooling was close in time to the end of deposition within the forearc basin and is consistent with structural evidence for Cretaceous deformation in a strike slip setting. The accelerated early Tertiary cooling episode was broadly coeval with, and may have been caused by ridge-trench collisions and cessation of subduction off-shore Alexander Island.

Fossil Bluff Group

The Fossil Bluff Group is up to 7 km thick and consists dominantly of silty mudstone, with significant amounts of sandstone and conglomerate. Palaeocurrent and provenance analysis indicate that the bulk of the unit was derived from the volcanic arc to the east (Butterworth and macDonald 1991), although there is a minor component of accretionary complex-derived material mainly in the western parts of the group (Doubleday et al. 1993). Deposition of the group spanned Mid-Jurassic (?Bathonian) to Albian times and has been divided into two major stages of basin development punctuated by short duration tectonically induced events. The oldest Selene Nunataks and Atoll Nunataks formations, exposed on the western side of the basin, record the first stage, the transition from trench-slope to fore-arc basin sedimentation. These units were derived from the accretionary complex rather than the volcanic arc. All other strata in the basin are part of the second stage fore-arc basin sedimentation and form a large-scale, shallow upward cycle of Kimmeridgian to Albian age (Butterworth and Macdonald 1991).

The sequence was deformed by oblique NNW-SSE trending folds with an associated weak cleavage. The geometry of a range of

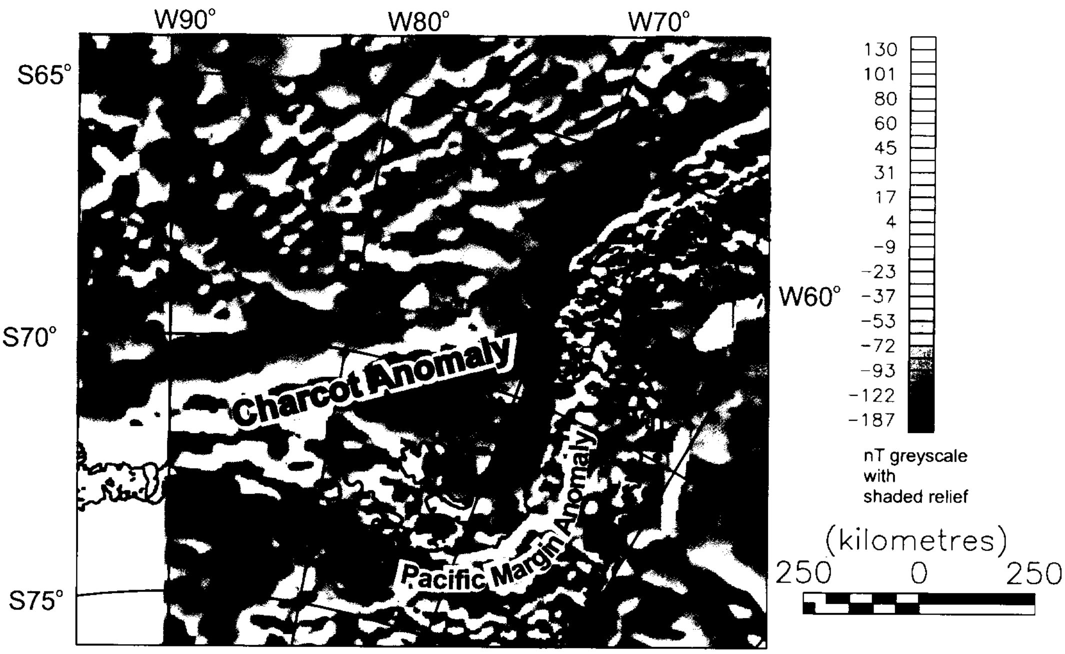

Figure 3. Aeromagnetic map of the Antarctic Peninsula showing the location of the curvilinear Pacific Margin Anomaly and the Charcot Anomaly on the outboard side of the Alexander Island accretionary prism.

related structures including bifurcating arrays of sandstone dykes, bedding parallel slip, conjugate normal faults and steep dextral normal oblique faults have been used to suggest that basin inversion involved dextral transpression (Storey and Nell 1988).

Magmatic history

A suite of Late Cretaceous to Early Tertiary (80 to 52 Ma) subduction-related magmatic rocks intruded the accretionary complex on Alexander Island (McCarron and Smellie 1998). The rocks occupy a fore-arc position 100-200 km trenchward of the main arc on the Antarctic Peninsula (Fig. 3). The magmatic rocks become younger northward along the length of the island. Although many of the igneous rocks on Alexander Island do not show magmetic anomalies, a prominent anomaly, the Charcot anomaly reaches amplitudes of 700 nT and forms a linear belt on the western side of the accretionary prism (Fig. 3) close to the inferred position of the trench. This is marked contrast to the location of the arcuate Pacific Margin Anomaly (PMA) representing the position of the Mesozoic magmatic arc. The arcuate nature of the PMA bordering the embayment within which the accretionary complex rocks occur suggests that the arc may nave been subjected to oroclinal bending with the accretionary prism having accumulated in the resulting embayment. Following the collision and docking of the large ocean island within this embayment and the further build up of the prism, the migration of the magmatic focus trenchward may have resulted in the emplacement of arc rocks in the prism and the Charcot Island anomaly. Alternatively, the Charcot Anomaly may represent a linear slice of ocean floor rocks although this seems unlikely as similar rocks within the accretionary prism do not form prominent magnetic anomalie.

Conclusions

The LeMay Group on the western side of the Antarctic Peninsula is an unusually wide Mesozoic accretionary complex. It is comprised of deformed trench-fill turbidites, trench slope sequences, allochthonous slivers of Late Jurassic to Early Cretaceous and mid Cretaceous ocean floor and a large ocean island of early Jurassic age centered on the Lully Foothills. Although the age of accretion of the prism is unknown, tectonic models suggest that some of it formed between 85 and 96 Ma. Oroclinal bending of the Antarctic Peninsula magmatic arc may account, at least in part, for the unusually wide complex now preserved in an arcuate embayment along the margin.

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