Table 1. Adsorption of ^3H-labeled L-alanine by *d*- and *l*-quartz.

Item	Radioactivity (counts per 5 minutes ± S.D.)		
	l-Quartz		*d*-Quartz
Control	221,853 ± 903		221,853 ± 903
Supernatant	158,957 ± 1,571		162,844 ± 763
Loss	62,896 ± 1,812		59,009 ± 1,182
Loss difference		3,887 ± 1,746	
Adsorbed (%)*	28.35 ± 0.82		26.60 ± 0.53
DA (%)†		1.75 ± 0.78	

* Ratio of 100 times the count loss to the control count. † Differential of adsorption (DA) is the ratio of 100 times the count loss difference to the control count, or the percentage adsorption by *l*-quartz minus the percentage adsorption by *d*-quartz.

million) to make a $2 \times 10^{-5}M$ solution (stored under septum). A 9.5-ml portion was removed with a hypodermic syringe and introduced onto 7.5 g of dried (170°C, 3 hours, about 0.1 torr) quartz powder (120 to 250 mesh; the surface was calculated to be about 250 cm^2/g) contained in a septum-stoppered flask with an outlet for a vacuum line. The mixture was stirred magnetically for 1 hour and allowed to settle for 3 hours. Triplicate portions of the supernatant were removed in sequence and placed in a liquid scintillation counter; each was counted in triplicate, and the resulting nine separate countings were averaged. Nine similar countings on three portions of the original untreated DMF solution were conducted consecutively as the control. Table 2 indicates the approximate reproducibility of a series of such experiments with both D- and L-alanine. No adsorption of radioactive alanine was observed when the solvent was water or aqueous alcohol. The DMF was scrupulously dried, and the experiments were performed in a closed system since greater amounts of water in the DMF were adsorbed in preference to or in competition with the alanine, leading to random, nonreproducible adsorption values. The quartz powder was completely freed of physically adsorbed water by the technique employed, as indicated by control experiments with radioactive ^3H_2O.

Table 2 shows that the total adsorption of alanine by quartz from $2 \times 10^{-5}M$ anhydrous DMF solution amounts to some 20 to 30 percent under the conditions employed, corresponding to a gross adsorption of about 0.5 to 0.7 μg of alanine per gram of quartz. Furthermore, *l*-quartz adsorbs L-alanine preferentially and *d*-quartz adsorbs D-alanine, the "differential adsorption" varying between 1.0 and 1.8 percent. Standard statistical evaluation (*t*-test) of the data on which Table 2 is based suggests that the differential adsorption figures shown are valid at the 99.9 percent confidence level.

In view of the negative results obtained by Amariglio *et al.* (*2*) and their critique of the earlier literature, we believe that the above experiments performed under aprotic, anhydrous conditions may constitute the first valid demonstration of the ability of quartz to bind optically active substrates with an asymmetric bias. However, since our present observed differential adsorption is small in comparison with the total adsorption, we feel obliged to confirm our observations, using D,L-amino acids and column chromatography, along with gas chromatographic evaluation (*5*) of the enantiomeric composition of our eluates. The implications of such observations for the abiotic origin of optically active organic molecules in nature have been reviewed (*1*).

Table 2. Replicate adsorptions of alanine by *d*- and *l*-quartz.

Form	Percentage (± S.D.) adsorption by:		DA (%)*
	l-Quartz	*d*-Quartz	
L	29.35 ± .43	28.33 ± .47	1.02 ± .29
L	28.35 ± .82	26.60 ± .53	1.75 ± .78
L	22.21 ± .42	21.03 ± .45	1.18 ± .53
D	29.08 ± .59	30.38 ± .81	−1.30 ± .65
D	25.92 ± .63	26.88 ± .66	−0.96 ± .44

* The differential adsorption (DA) is the percentage adsorption of *l*-quartz minus the percentage adsorption by *d*-quartz. The use of ± indicates standard deviation.

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Development of the Circum-Antarctic Current

Abstract. *Deep-sea drilling in the Southern Ocean south of Australia and New Zealand shows that the Circum-Antarctic Current developed about 30 million years ago in the middle to late Oligocene when final separation occurred between Antarctica and the continental South Tasman Rise. Australia had commenced drifting northward from Antarctica 20 million years before this.*

One of the main objectives of Leg 29 of the Deep-Sea Drilling Project was to determine the evolution of the Circum-Antarctic Current south of Australia and New Zealand and to decipher its effects on Cenozoic deep-sea sedimentation in the Southern and South Pacific oceans. Several sites were drilled to evaluate the development of this major current system (*1*).

The Circum-Antarctic Current is of great oceanographic and climatic importance because it transports more than 200×10^6 m^3 of water per second, probably the largest volume transport of any ocean current (*2, 3*). It also circulates completely around Antarctica, mixing waters of all oceans. The combined effects of plate tectonic movements at high southern latitudes and Antarctic glacial development during the last 60 million years have led to the formation of the present Circum-Antarctic Current. Initial development of the Circum-Antarctic Current resulted from the opening of the final constricting region south of Australia. Earlier separations had already occurred south of New Zealand and in the Drake Passage south of South America (*4*). Magnetic anomalies adjacent to New Zealand record the separation of New Zealand from Australia and Antarctica 60 to 80 million years ago, forming the Tasman Sea between Australia and New Zealand, while Australia remained firmly connected with Antarctica (*5–7*). Approximately 55 million years ago spreading ceased in the Tasman Sea region, and Australia detached from Antarctica and commenced drifting northward toward its present position (*5*).

The history of sedimentation in Leg 29 sites records the gradual evolution of the southwest Pacific Basin, the Tasman Basin, and the southwest Indian Ocean and related major paleocirculation changes. With the exception of rare occurrences of detrital or glauconitic sands, the sediments can be grouped into three facies: terrigenous silt and clay, siliceous ooze, and calcareous ooze-chalk. At several sites these facies succeed each other in this order. During initial rifting the continental regions were closer together and circulation was relatively sluggish. This resulted in deposition of the terrigenous silt and clay facies. The age of this facies is diachronous throughout the region, reflecting different ages for the initiation of the basins. Sluggish circulation occurred during the Late Cretaceous in the vicinity of the Campbell Plateau (southwest Pacific Ocean), during the Paleocene and Eocene in the Tasman Sea Basin, and during the Eocene and Oligocene in the southwest Indian Ocean between Australia and Antarctica. With continued sea-floor spreading and increased basinal development, more open-ocean conditions developed, terrigenous sediment sources became more distant, and increased biogenic productivity formed Oligocene biogenic ooze. This, in general, is succeeded in the deep basins and on the shallow-water Campbell Plateau by a poorly represented Neogene sequence highly disrupted by one or several major disconformities reflecting highly active bottom currents.

The South Tasman Rise is a feature of major importance in the Southern Ocean. Site 281, located on the southern part of the rise, bottomed in middle Paleozoic mica schist, proving that the rise is continental and not formed by postrift volcanism (*1*). This has important paleoceanographic implications, since the Circum-Antarctic Current could not have formed until the South Tasman Rise (rather than Tasmania) cleared the northern tip of Victoria Land, Antarctica. The sedimentary successions at Sites 280, 281, and 282 drilled adjacent to Tasmania are the most critical as these clearly record early basinal evolution, the evolution of oceanic conditions, and finally the development of the Circum-Antarctic Current itself (Fig. 1).

At Site 280, located in deep water south of the South Tasman Rise, the initial sediments of Eocene age are terrigenous silt and clay facies, deposited at a basin margin relatively near the center of the basin. The lack of primary sedimentary structures and poor sediment sorting suggest sluggish bottom-water circulation. Very high organic content indicates that the basin was also rather poorly oxygenated during much of the deposition. Relatively high sedimentation rates in this deep basinal area reflect a nearby source of the detrital sediments, while very low biogenic content probably indicates very low siliceous productivity during the middle and late Eocene. The terrigenous silt and clay facies grades up into Oligocene siliceous oozes (Fig. 1) in which diverse, well-preserved diatoms are dominant; this indicates an increase of productivity resulting from open-ocean circulation commencing in the latest Eocene and continuing into the Oligocene. At that time decreased deposition of detrital sediments occurred, probably reflecting movement of the depositional site away from the source of supply.

The record of continued sedimentation in the Paleogene is abruptly terminated at the beginning of the Neogene. The near absence of most of the Neogene (Fig. 1) is due to the development of high-velocity deep-sea bottom currents through the area, reflecting the development of high-velocity circumpolar flow south of the South Tasman Rise. During the late Eocene, although no deep-water circulation existed south of the South Tasman Rise, the southwest Pacific and southeast Indian oceans were connected across the shallow South Tasman Rise (*1, 8*). Despite this, the lack of strong bottom currents indicates that no shallow proto-Circum-Antarctic

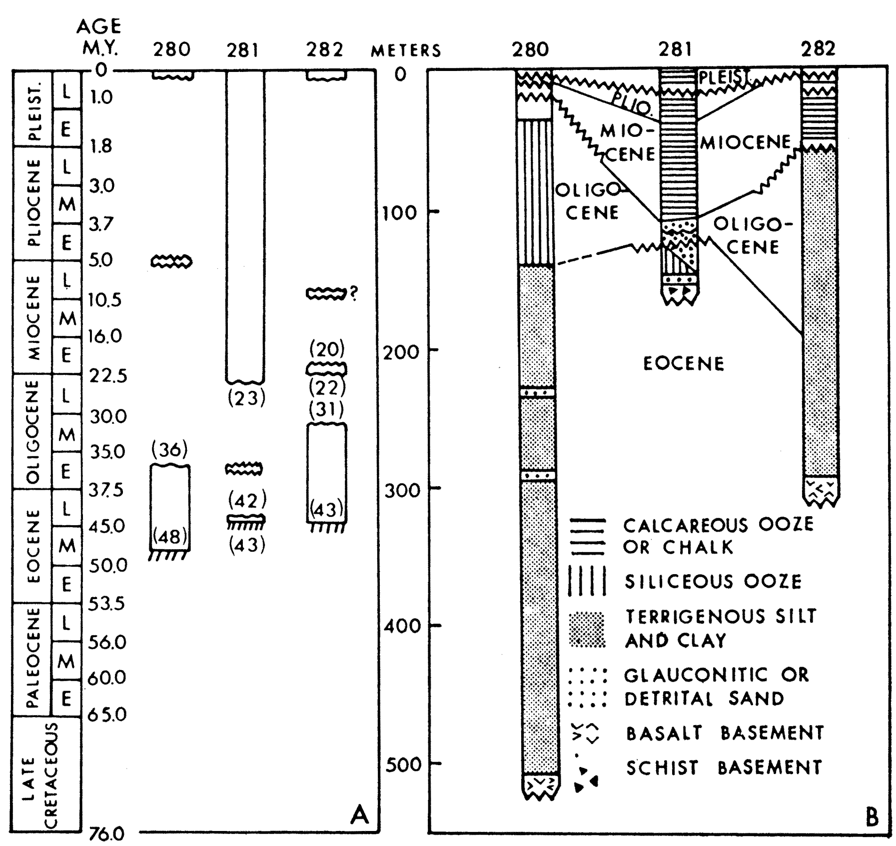

Fig. 1. (A) Ages of sediments (millions of years) and (B) simplified stratigraphy of three critical sites drilled during Leg 29 of the Deep-Sea Drilling Project. The purpose was to evaluate the sedimentary changes resulting from oceanic evolution when Australia and Antarctica separated, and the development of the Circum-Antarctic Current. Site 281 is shallow (1591 m) on the South Tasman Rise; Sites 280 and 282 are deep (4176 m and 4202 m). In (A) the figures in parentheses are the assumed ages of the strata on either side of unconformities or at the bottoms of holes. Basement is indicated by hachures. The time scale is after Berggren (*16*). In (B) sedimentary sections are plotted against thickness in meters; unconformities are indicated.

Current was then in existence. Toward the end of the Eocene, bottom currents increased to transportational or erosional intensity, producing disconformities or highly condensed sequences involving most of the Oligocene and late late Eocene (Fig. 1). At Site 281, unlike Sites 280 and 282, an uninterrupted Neogene sedimentary record of calcareous ooze is recorded. Reinitiation of sediment deposition in the earliest Miocene reflects diminishing current effects as the rise moved northward and Circum-Antarctic flow established its position south of the South Tasman Rise, similar to the present-day position. From that time, much of the South Tasman Rise became a quiet area of pelagic biogenic sedimentation.

The evolution of the Circum-Antarctic Current south of Australia and New Zealand can be traced by a series of maps (Fig. 2). In the Late Cretaceous and Paleocene, Australia and Antarctica were joined (*5*) and no Circum-Antarctic Current existed. The Tasman Sea region was expanding (*7*). Earlier in the Late Cretaceous, terrigenous sediments were initially deposited in restricted basins on the Campbell Plateau, which was adjacent to Antarctica. Later within the Late Cretaceous, increasing rich siliceous biogenic sediments reflect the development of more oceanic conditions (*1*).

By the late middle Eocene and late Eocene (Fig. 2A), a substantial ocean had developed between much of Australia and Antarctica. Spreading appears to have been a diachronous event beginning in the west and propagating eastward, with resulting diachronism in sedimentation. In the middle Eocene, truly marine conditions first appeared in the Eucla and Otway basins in central southern Australia, with a diachronous west-east trend (*9*). The South Tasman Rise and Tasmania protruded far southward from the main Australian continent and continued to block Circum-Antarctic flow. The seaway between Tasmania and Australia remained closed by highlands (*10*). Oceanic crust formed in the region southwest of Tasmania and the South Tasman Rise during the late middle to late Eocene (Sites 280 and 282). By late Eocene a very shallow marine connection was established across the South Tasman Rise. The shallowness of this marine connection between the southwest Pacific and southeast Indian oceans prevented the development of active bottom currents. During most of the Eocene, surface-water temperatures in the Southern Ocean were considerably higher than at any time since (*11*). Glaciation on Antarctica during this time was most likely restricted to high altitudes, although the presence of ice-rafted debris and low planktonic foraminiferal diversity in southwest Pacific Eocene sediments indicate at least some glaciation at sea level (*12*). About 38 million years ago near the Eocene-Oligocene boundary (Fig. 2B), the sediment patterns in the southwest Pacific began to be extensively disrupted by bottom-water circulation resulting from the production of Antarctic bottom water much like the present-day production (*11*). Resulting active deep-sea erosion continued throughout much of the Oligocene, which was relatively cool, and formed the Oligocene oceanic hiatus, which is particularly pronounced in the western parts of oceans. A regional Oligocene unconformity in the Tasman Sea and Coral Sea regions (*13*) was formed by actively eroding bottom currents derived from the Ross Sea sector of Antarctica flowing northward as a broad western boundary current (*13*). During the early Oligocene (Fig. 2B), the South Tasman Rise still had not moved sufficiently north to create a Circum-Antarctic Current. The increasingly oceanic conditions of the deep basins immediately adjacent to Tasmania and the South Tasman Rise were heralded in the Oligocene by the deposition of deep-sea biogenic oozes. Bottom-water circulation was still restricted, and no evidence exists within the early Oligocene of erosion in these deep basins.

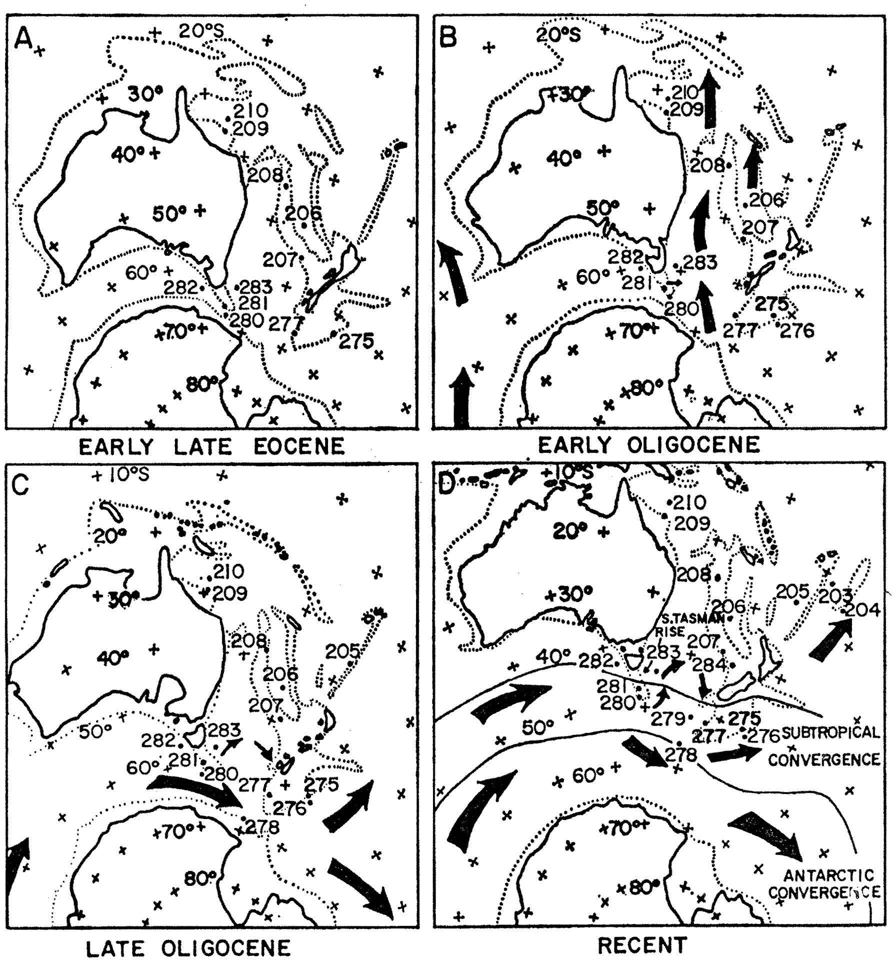

Fig. 2. Successive Cenozoic reconstructions of Australia, Antarctica, New Zealand, and associated ridges during (A) early late Eocene (45 million years ago), (B) early Oligocene (37 million years ago), (C) late Oligocene (30 million years ago), and (D) Recent. Directions of bottom-water circulation are shown by arrows. Land areas and shallow ridges and rises are marked. During the early Oligocene (B) extensive erosive bottom currents flowed northward through the Tasman and Coral seas. The Circum-Antarctic Current did not develop until about the late Oligocene (C), and a strong northward-flowing western boundary current formed to the east of New Zealand. These directions have been retained to the present day (*2*). Continental reconstructions after Weissel and Hayes (*5*) and Hayes and Ringis (*7*). Site numbers indicate sites drilled during Legs 21 and 29 of the Deep-Sea Drilling Project.

However, a hiatus or highly condensed sequence, representing the latest Eocene and Oligocene, reflects a prolonged interval of bottom erosion over the shallow-water South Tasman Rise. This hiatus is equivalent to that in the Tasman Sea, Coral Sea (*13*), and other oceanic sequences throughout the world (*14*), and appears to reflect intensified oceanic circulation resulting from Antarctic glacial development.

During the middle to late Oligocene, about 25 to 30 million years ago (Fig. 2C), a drastic change in regional sediment patterns occurred throughout the southwest Pacific region and in the Southern Ocean. At this time the opening developed between the southern part of the South Tasman Rise and Antarctica, creating an active Circum-Antarctic deep-sea circulation. As a result, the deep basins adjacent to Tasmania and the South Tasman Rise have virtually no sedimentary record for the entire Neogene and Oligocene (the last 30 million years). On the Campbell Plateau (Site 277), continuous Paleogene calcareous oozes underlie a major hiatus spanning the latest Oligocene to Pleistocene (*1*). This change from deposition to erosion near the Neogene-Paleogene boundary almost certainly resulted from highly active bottom currents over the plateau related to Antarctic current development and the establishment of a highly eroding western boundary current system to the east of New Zealand (Fig. 2C). The absence of extensive bottom-current erosion in the northern Tasman-Coral Sea regions since the Oligocene is due to the diversion of important northward-flowing bottom currents from the Tasman Sea to the east of New Zealand. This diversion resulted from either the development of topographic barriers in the northern Tasman Sea or the deflection of potentially northward-flowing bottom currents by the active Circum-Antarctic Current. The Lord Howe Rise had already developed by the Late Cretaceous in the northern Tasman Sea (*13*), and hence the development of the Circum-Antarctic Current appears to have created the paleocirculation changes rather than deep-sea topographic changes in the northern Tasman Sea. Sediment distribution in the region suggests that no major changes have occurred in deep-sea circulation patterns since the late Oligocene (Fig. 2D), although further major changes have occurred in the intensity of bottom-water flow (*15*) and in the development of the Antarctic Convergence. The separation of Australia from Antarctica led to a fundamental change in the world's oceanic circulation and its climate that marks the onset of the modern climatic regime.

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Bone Foreshafts from a Clovis Burial in Southwestern Montana

Abstract. *Formal and functional analyses of bone artifacts from a Clovis burial in southwestern Montana suggest that they were constructed to serve as (detachable or nondetachable) foreshafts for attaching fluted projectile points to lance shafts.*

The late Pleistocene technological system accepted by most scholars as being representative of the first groups of hunters has been consistently radiocarbon-dated between 10,960 and 11,500 years before present (*1*, pp. 77–92). The primary evidence for the existence of these peoples was found first at Dent, Colorado, in 1932 and later in the Llano Estacado area near Clovis, New Mexico. Hence, the name "Clovis" has been used specifically for the temporal, spatial, and technologically distinctive type of fluted stone projectile point utilized by them, and as a general index for an entire cultural system (*2*).

At present, the source data in the western United States for the Clovis