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1. GEOLOGICAL BACKGROUND AND OBJECTIVES[1]

Shipboard Scientific Party[2]

INTRODUCTION

The region of the Chile Trench between about 45°40S and 47°S is the site of a collision between the actively spreading Chile Ridge and the Chile Trench subduction zone (Herron et al., 1981; Cande and Leslie, 1986; Cande et al., 1987). Here, the Nazca Plate, the Antarctic Plate, and the spreading ridge that separates them, are being subducted eastward beneath South America along the Peru-Chile Trench. The Chile Triple Junction region is one of only two examples where a spreading mid-ocean ridge is actively being subducted, an event that has occurred elsewhere along the convergent margins of the Pacific Ocean basin in the geologic past. Spreading-ridge subduction events are likely to leave distinctive structural and stratigraphic signatures in the geological record of the overriding plate, including: (1) rapid uplift and subsidence of the arc and forearc (de Long and Fox, 1977; de Long et al., 1978, 1979), (2) high levels of regional metamorphism and elevated thermal gradients, (3) a hiatus in arc magmatism, (4) anomalous near-trench and forearc magmatism (Marshak and Karig, 1977), and (5) localized subsidence and extensional deformation of the forearc in the region of the collision (Herron et al., 1981; Barker, 1982). Hydrothermal alteration, anomalous diagenesis, and mineralization of forearc materials can also be expected, driven by the hot fluids venting from the subducting spreading ridge.

In addition to the structural, magmatic, and hydrothermal effects active at the ridge/trench collision, the Chile Triple Junction region is the likely site of current emplacement of a fragment of oceanic crust into the landward trench slope. A bathymetric ridge that forms a promontory extending out from the base of the trench slope south of the collision zone, the Taitao Ridge, may represent a fragment of oceanic crust in the process of emplacement into the South American continental margin. Interpretations of marine magnetics data, bathymetric data, and CDP reflection profiles all suggest that the Taitao Ridge may constitute an ophiolite terrane.

One major result of ridge/trench collision is the rapid removal of forearc material from the overriding plate (Herron et al., 1981; Cande and Leslie, 1986; Cande et al., 1987). Models of ridge/trench interaction predict that material is eroded from the overriding plate by both subduction erosion at depth in the subduction zone, and by surficial slumping and extensional faulting of the upper levels of the forearc. The Chile forearc is extremely narrow in the vicinity of the triple junction, but broadens both to the north and south. The southern region represents the rebuilding of the accretionary prism and forearc basin following the partial destruction of the forearc associated with the passage of the triple junction along the margin, while north of the triple junction the margin has yet to be subjected to the subduction erosion processes associated with the ridge subduction.

TECTONIC SETTING AND REGIONAL GEOLOGY

The Chile margin Triple Junction represents the only presently active ridge-trench collision where the overriding plate is composed of continental lithosphere. Regional plate tectonic reconstructions for the southern Chile Triple Junction are well constrained by marine magnetic anomaly studies (Pilger, 1978; Cande et al., 1982), so the detailed relationships between plate motions and continental margin geology can be effectively studied here. These reconstructions show that the Chile Ridge first collided with the Chile Trench about 14 Ma near the latitude of Tierra del Fuego (Fig. 1). A long ridge segment was subducted between Tierra del Fuego and the Golfo de Penas between roughly 10 and 14 Ma, another ridge segment was subducted adjacent to the Golfo de Penas (and perhaps partially overlapping with the Taitao Peninsula) at about 6 Ma, and a short ridge segment was subducted adjacent to the Taitao Peninsula at about 3 Ma.

The relative plate motion vector between the Antarctic and South American plates is different from that between the Nazca and South American plates. Hence, as the triple junction migrates northward along the margin, the relative motion vectors between the subducting and overriding plates change. North of the advancing ridge-trench collision the Nazca Plate is subducted at a rapid rate (roughly 80 mm/yr for the past 3 m.y., and as fast as 130 mm/yr during the late Miocene) in a direction slightly north of east. Following the passage of the triple junction, the Antarctic Plate is subducted at a much slower rate, roughly 20 mm/yr for the past 15 m.y., in a direction slightly south of east (Chase, 1978).

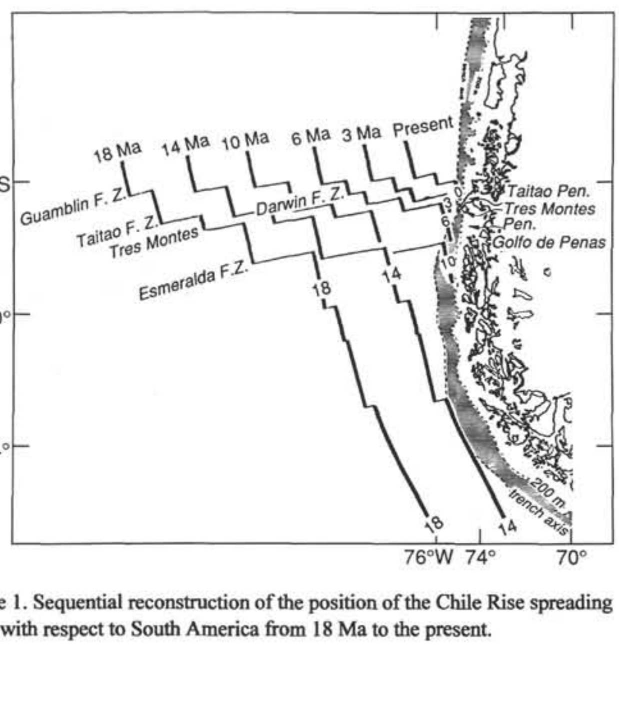

Figure 1. Sequential reconstruction of the position of the Chile Rise spreading ridge with respect to South America from 18 Ma to the present.

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[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

New SeaBeam bathymetric data accurately delineate the present-day geometry and location of the ridge-trench collision. The Chile Ridge spreading center intersects the Chile Trench at 46°12S. The spreading ridge strikes nearly parallel to the trench, resulting in a highly oblique ridge-trench collision, while the fracture zones that offset the Chile Ridge strike about 20° from perpendicular to the trench.

The on-land geology of southern Chile, while not mapped in detail, is reasonably well known at a regional level (Servicio Nacional de Geologia Y Mineria, 1980), and local areas near the triple junction have been the subject of recent field work (Forsythe and Nelson, 1985; Prior et al., 1990). Exposures in the area near the triple junction are dominated by four principal lithologies: (1) pre-Late Jurassic metamorphic rocks, forming the pre-Andean South American basement, (2) the largely Mesozoic-aged Patagonian batholith, (3) Mesozoic and Cenozoic volcanic rocks associated with the Patagonian batholith, and (4) Neogene sedimentary and igneous rocks (Servicio Nacional de Geologia Y Mineria, 1980; Forsythe and Nelson, 1985). Additional important but areally limited rock types include an unusual suite of young (Pliocene-Pleistocene) granodioritic plutons in and around the Golfo Tres Montes within about 20 km of the trench axis and about 150 km seaward of the main axis of the Quaternary Andean volcanic arc, and a tilted but apparently coherent Pliocene-aged ophiolite sequence on the Taitao Peninsula (Fig. 2; Forsythe et al., 1986).

DRILLING OBJECTIVES

The drilling objectives for the southern Chile margin were focused on the effects of spreading-ridge subduction. Geophysical studies suggest that the major effect of the collision is gradually accelerating tectonic erosion, manifested by rapid subsidence of the forearc. Forearc subsidence dominates the processes acting along the margin before the ridge arrives at the trench. Subsidence culminates in a period of rapid tectonic erosion when the ridge is subducted. This event is followed by a period of accretion that transfers new material from the subducting oceanic plate into the forearc. The basic objectives of the drilling program were: (1) to test this model of accelerated subduction erosion and (2) to explore the mechanisms responsible for subduction erosion. The fundamental tectonic questions addressed during Leg 141 include:

1. The timing, rate, amplitude, and regional extent of vertical motion within the forearc that results from the ridge/trench collision.
2. The seaward limit of continental crust along the Chile margin forearc in the vicinity of the ridge/trench collision.
3. The nature, petrology, distribution, and chemical affinities of near-trench volcanism associated with the ridge-trench collision.

Previous investigations of the triple junction region and the newly acquired data all suggest that this area is undergoing extensive tectonic erosion (Cande and Leslie, 1986; Cande et al., 1987). Although tectonic erosion is probably occurring along other sections of the Peru-Chile Trench and other active margins (von Huene, 1986), this process is exceptionally advanced near the triple junction. The trench slope is narrower and steeper around the triple junction than anywhere else along the Peru-Chile Trench system. We infer that within the collision zone not only the accretionary prism, but also the continental basement are being eroded. Forearc basement reflectors extend seaward to within a few kilometers of the base of the trench slope, and forearc basement is often offset down toward the trench on normal faults.

FOREARC GAS HYDRATES, THERMAL HISTORY, AND FLUID MIGRATION

The critical role of pore-fluid pressure and fluid movement has been documented for the process of subduction accretion in several trenches (Mascle, Moore, et al., 1988; Taira, Hill, Firth, et al., 1991). Little is known about fluid flow in trenches characterized by subduction erosion, but pore waters carried rapidly beneath the forearc are likely to play an important role in the deformation process. Fluids probably migrate along faults controlled by both the oceanic crustal fabric and the structural fabric of the deforming accretionary wedge near the toe of the trench as pathways to the ocean floor, and along faults and fractures in the continental basement further landward within the forearc.

A bottom-simulating reflector (BSR) is recognized in seismic reflection profiles in the region of the triple junction, and is interpreted to indicate the presence below seafloor of frozen gas hydrates or clathrates. The following issues need to be addressed to understand the nature and significance of marine gas hydrates.

1. The sources and generation processes of the gases that are involved in hydrate formation;
2. The amount of gas hydrate in the triple junction region;
3. The amount and nature of free gas that exists beneath the BSR;
4. The composition, generation, and flow pathways of the fluids and gases within, above, and beneath the hydrate; and
5. The physical properties and diagenetic pathways of the sediments that are cemented by hydrate, those that undergo hydrate breakdown, and those that are cemented by carbonate precipitation resulting from methane oxidation to carbon dioxide.

OPHIOLITE EMPLACEMENT

The Taitao Ridge is a bathymetric feature that projects out from the landward trench slope above the trace of the Taitao Fracture Zone (Fig. 2). The ridge is interpreted to be oceanic in origin as it has two linear magnetic anomalies that strike roughly parallel to seafloor spreading anomalies further north that are clearly related to the axis of the Chile Ridge (Fig. 3). However, it is not clear whether this fragment of oceanic crust is part of the subducting Antarctic Plate or whether it has been (or is in the process of being) obducted onto the landward trench slope. The geochemical analysis of the igneous basement of the Taitao Ridge can ascertain whether the Taitao Ridge is an offshore extension of the Taitao ophiolite or has some other origin. If it is an ophiolite, the geology of the Taitao Ridge and its structural evolution may serve as a prototype for the incorporation of ophiolites into convergent and collisional plate margins and therefore into orogenic belts.

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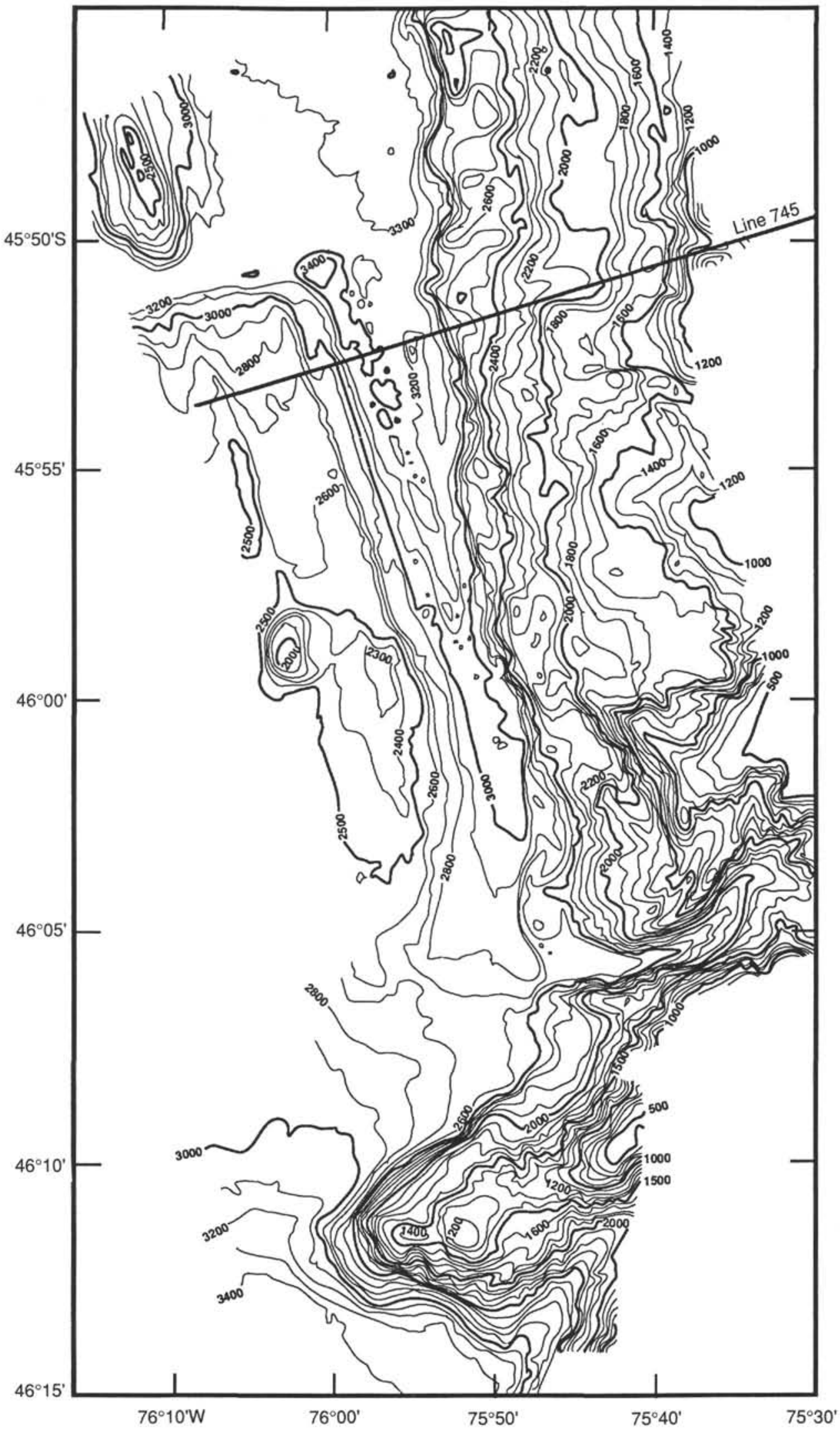

Figure 2. Bathymetric map of the Chile Margin Triple Junction region showing CDP dat coverage and place names.

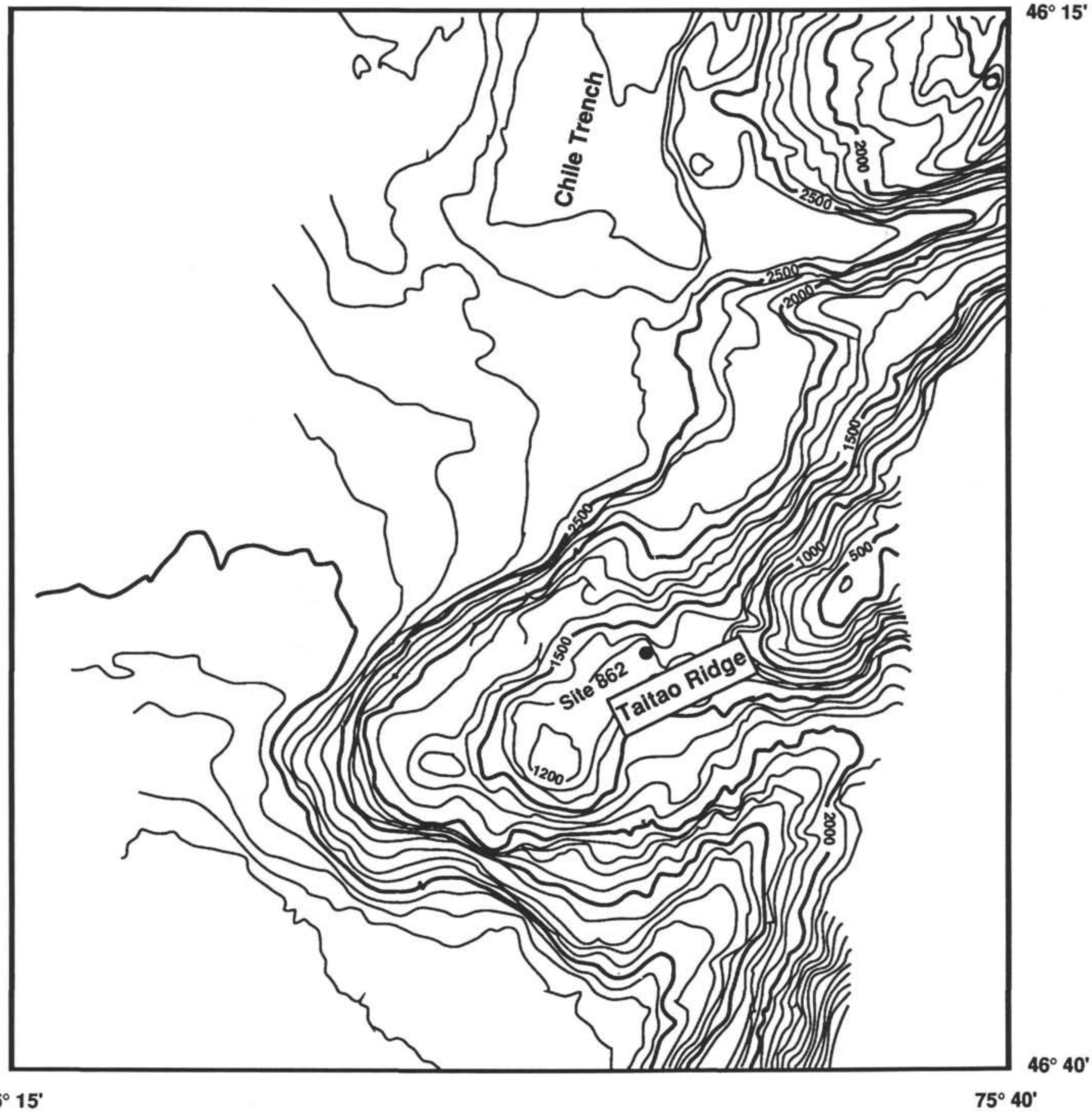

Figure 3. Bathymetric map of the Taitao Ridge, showing marine magnetic anomalies over the ridge.