*Tectonophysics,* 163 (1989) 13–24
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

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# Evidence for the subduction and underplating of an oceanic plateau beneath the south Peruvian margin during the late Cretaceous: structural implications

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(Received March 28, 1988; revised version accepted September 26, 1988)

## Abstract

Soler, P., Carlier, G. and Marocco, R., 1989. Evidence for the subduction and underplating of an oceanic plateau beneath the south Peruvian margin during the late Cretaceous: structural implications. *Tectonophysics,* 163: 13–24.

During late Cretaceous times (Santonian to Maastrichtian), the southern Peruvian and northernmost Chilean Andes show a series of tectonic, magmatic and sedimentological features, which appear to be specific to this area when compared with northern and southern parts of the Andes: a gap in the magmatic activity in the Coastal Range and the Western Cordillera between 84 and 70 Ma; huge overthrusting faults involving the Precambrian basement in the Arequipa region; and the syntectonic filling of the Cuzco and Sicuani foreland continental basins. These particular features may be regarded as consequences of the subduction and underplating of a paleo-oceanic plateau (the "Mollendo ridge") which would have occurred in this area between ±85 and ±70 Ma B.P. with an almost N–S direction of convergence between the Farallon and South American plates.

This inferred "Mollendo ridge" would have been an eastern equivalent of the present-day Manihiki plateau of the western Pacific Ocean.

The proposed model provides new elements for the interpretation of the subsequent structural and magmatic evolution of the central Andes; it permits the explanation of the particular location and the petrochemical and metallogenetic features of the Andahuaylas–Yauri batholith. The segment of abnormally thick crust created by the underplating of the "Mollendo ridge" and by overthrusting tectonics will act as an accumulation point for further Cenozoic deformation along the Andean margin; then the subduction of the "Mollendo ridge" would mark the outset of the development of the oroclinal bending of the central Andes (the Arica elbow) and of the associated Altiplano and its anomalous thick crust.

## Introduction

Aseismic ridges, intra-plate islands and/or seamount chains, and oceanic plateaus are common features of the subducted oceanic lithosphere in present-day active margins, especially in various areas around the Pacific Ocean. These anomalous portions of the oceanic lithosphere have been demonstrated to be more buoyant than the surrounding oceanic lithosphere, because of their thick crustal roots, as in the case of aseismic ridges and oceanic plateaus, or because of their relatively young and warm crust, as in the case of the islands and seamount chains (Vogt, 1973; Vogt et al., 1976; Kelleher and McCann, 1976; Cross and Pilger, 1982). The subduction of such abnormally buoyant topographic highs produces a decrease in the dip of the subducted plate. The more classic examples of such an interaction are given by the Louisville ridge in the Tonga–Kermadec, the Marcus–Necker ridge in the Bonin, the Kiushu–Palau ridge in southern Japan, the Kodiak–Bowie seamount chain in the Aleutians, the Cocos ridge in Central America and the Nazca ridge and Juan Fernandez islands–seamounts chain in western South America. In the case of a young oceanic crust being subducted and of an upper plate overriding the trench (in the absolute motion frame), as in the western margin of South America, the "normal" subduction dip is already low (±30°) (Stauder, 1973, 1975, Barazangi and Isacks, 1976, 1979; Hasegawa and Sacks, 1981; Grange et al., 1984; Cahill and Isacks, 1985) and the decrease in the dip of the slab associated with the subduction of the ridges appears to be sufficient to displace the asthenospheric wedge between the upper continental lithosphere and the subducting oceanic lithosphere and then to prevent arc magma production (e.g. Barazangi and Isacks, 1976).

The presence of such anomalous portions of the oceanic lithosphere is so common and so widespread in present-day active margins that it may be intuitively deduced that subduction of palaeoridges has occurred in many places during geological time. However, unequivocal arguments to demonstrate such a process to have succeeded are scarce, because the geological features are too intricate and the radiochronological data on subduction-related magmatic rocks are insufficiently accurate and/or much too scattered to allow the identification of the tracks of such a spatially limited and relatively short-lived phenomenon.

We present here a set of tectonic, magmatic and sedimentological evidence that sustains a model according to which a palaeoridge or oceanic plateau has been subducted during late Cretaceous times beneath the margin of southern Peru. Some consequences of this event upon the subsequent structural and magmatic evolution of this part of the Andes are discussed.

## The distinctive features of southern Peru during the Late Cretaceous

In the central part (6–41°S) of the active margin of western South America, which corresponds to the present Central Andes, oceanic lithosphere has been subducting unceasingly beneath the continent for at least 200 m.y. (e.g. Mégard, 1978, 1989; Aguirre, 1985). Since the Late Triassic, geological features have been more or less continuous all along the central Andes, especially with respect to the space and time distribution of magmatic activity and tectonic events (Fig. 1). Those distributions would be related to variations in the modalities (rate and direction of convergence, dip of the Wadati–Benioff zone, etc.) of the subduction process (e.g. Frutos, 1981; Soler, 1987).

In this broad continuity, various segments of the Andes present anomalous features during different epochs. Among these anomalous segments, the southern Peruvian and northernmost Chilean Andes show various Late Cretaceous features which appear to be specific to this area when compared with northern and southern segments of the central Andes at that time.

### *Specific magmatic features*

As emphasized in Fig. 1, an obvious particularity of this area, which first drew our attention, is the absence of magmatic activity between ≈ 84 Ma and ≈ 70 Ma. Available data shows that magmatic activity ceased in the coastal region of southern Peru (Fig. 2) after the setting of the Ilo (110–99 Ma) and Tiabaya (≈ 84 Ma) calc-alkaline, I-type, plutonic units (Beckinsale et al., 1985; Mukasa, 1986) and resumed with the setting of the Linga–Arequipa (71–67 Ma) (Estrada, 1978; LeBel et al., 1984; Mukasa, 1986). Yarabamba (67–59 Ma) (Beckinsale et al., 1985; Mukasa, 1986) and Toquepala (69–55 Ma) (Zimmerman and Kihien Collado, 1983; Beckinsale et al., 1985) calc-alkaline, I-type, plutonic suites and the deposition of the Toquepala calc-alkaline, mantle-derived (James et al., 1974) volcanics (Laughlin et al., 1968; Bellon and Lefèvre, 1976; Vatin-Pérignon et al., 1982; Zimmerman and Kihien Collado, 1983; Beckinsale et al., 1985). The available data

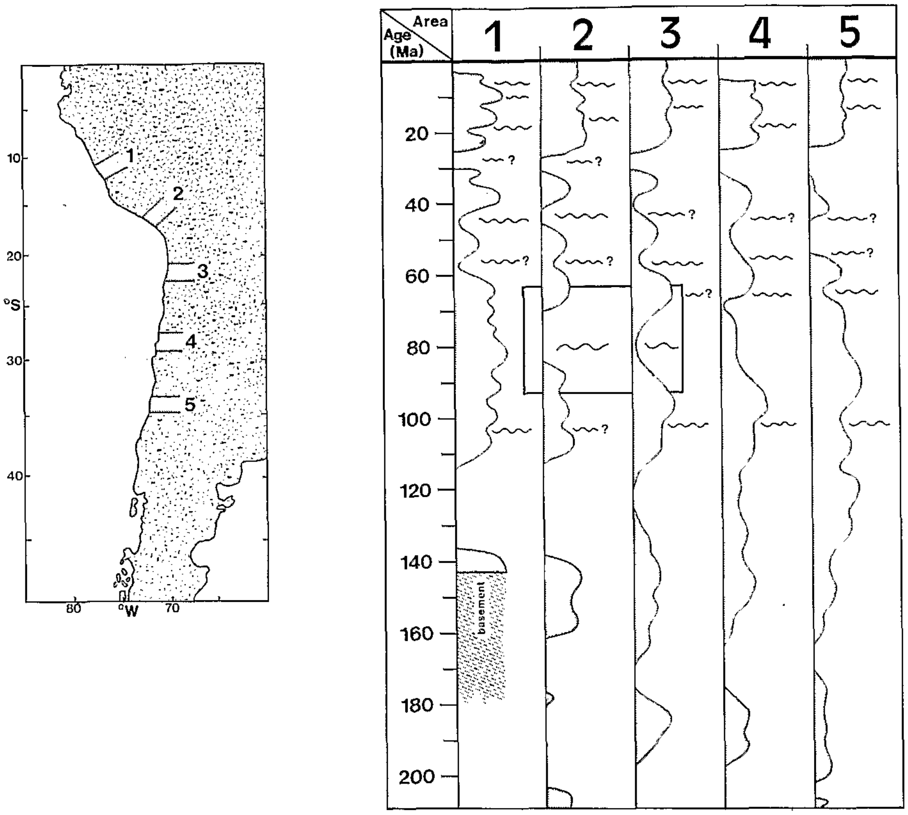

Fig. 1. Correlation of the major tectonic and magmatic events along the central Andes of Peru and Chile. Amplitudes are schematically proportional to the volume of magmatic products (from Soler, in prep.). The box underlines the epoch and area this paper is concerned with.

suggest the existence of a similar gap in magmatic activity in the northernmost Chilean Andes (Aguirre, 1985), where magmatic activity resumed in the latest Cretaceous (Huete et al., 1977; Maksaev, 1978; Montecinos, 1979). In contrast, this period (70–84 Ma) is characterized by very important magmatic activity, one of the most important active periods in the geological history of the margin, in central Peru (discussion and references in Cobbing et al., 1981 and Pitcher et al., 1985) and in north-central and central Chile (discussion and references in Aguirre, 1983, 1985).

### *Specific tectonic features*

In the area under consideration, Vicente et al. (1979) and Vicente (1989) demonstrated the existence of an important overthrusting which implicates the Precambrian basement and its Mesozoic pre-Santonian cover, with an horizontal displacement of at least 25 km to the north-northeast. They mapped or inferred this overthrusting from the Cotahuasi valley in the northwest to the Chilean border to the southeast (Fig. 2). These faults may have a prolongation in northernmost Chile (Vicente et al., 1979). Both by its style and age, this tectonic event appears as absolutely specific to the Western Cordillera of the Andes of southern Peru. In any other segment of the central Andes such a tectonic episode has been identified.

A tectonic episode of late Albian age has been reported in central and north-central Chile (the "Meso-Cretaceous or Subhercynian" phase of Aguirre et al., 1974) and in central Peru (the "Mochica" phase of Mégard, 1984 and Pitcher et al., 1985) but no tectonic episode has been identified between this Albian episode and the Laramian tectonic phases of the latest Cretaceous and the Palaeocene. The only other indication of Santonian deformation is given immediately to the

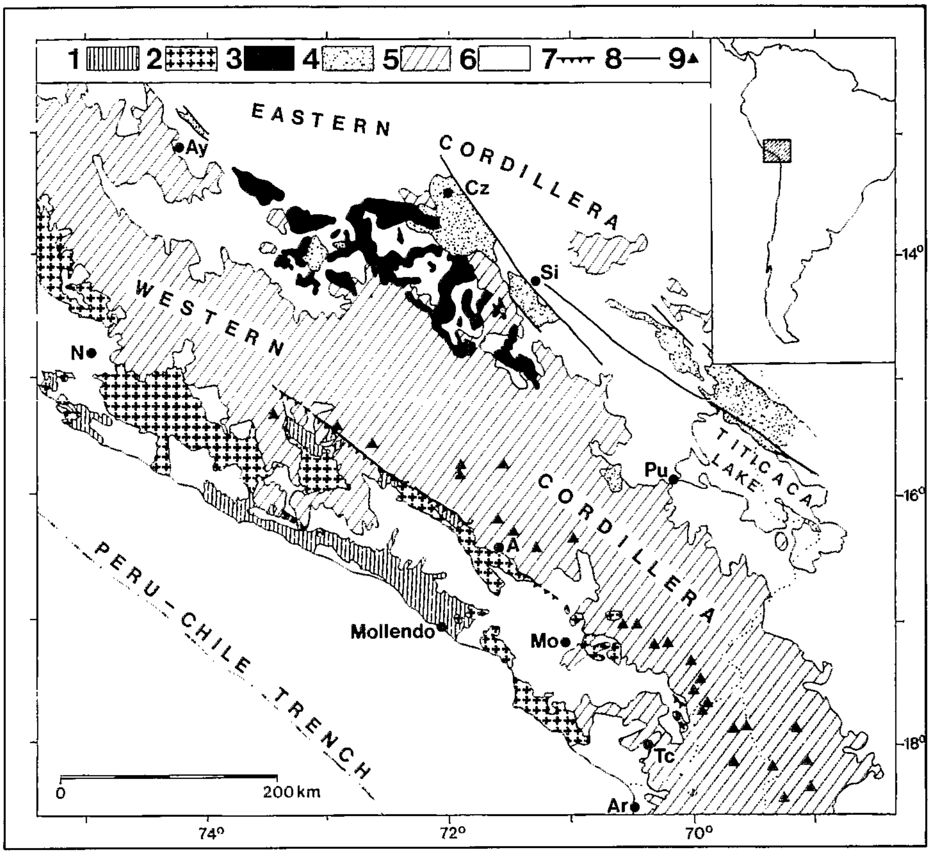

Fig. 2. Schematic geological map of southern Peru. *1* = Precambrian basement; *2* = Coastal Batholith; *3* = Andahuaylas–Yauri batholith; *4* = Red Beds continental basins; *5* = Cenozoic volcanism; *6* = other terrains; *7* = Arequipa overthrusting; *8* = main faults controlling the deposition of the Red Beds; *9* = Quaternary and active volcanoes. *Ay*—Ayacucho; *N*—Nazca; *Cz*—Cuzco; *Si*—Sicuani; *Pu*—Puno; *A*—Arequipa; *Mo*—Moquegua; *Tc*—Tacna; *Ar*—Arica.

north-northwest of the area under consideration by Mégard (1978) and Marocco (1978) in the Tambo–San Miguel area (east-northeast of Ayacucho, Fig. 2). In this area, along the western edge of the Eastern Cordillera, the Turonian and pre-Turonian cover is affected mainly by dextral wrench faults and minor folding prior to the deposition of the upper Cretaceous Red Beds.

Some of the dextral wrench faults which affect the Coastal Batholith (Bussell, 1983) and the western edge of the Eastern Cordillera (Mégard, 1978) in central Peru may be of Cretaceous age, but it has been demonstrated (Soler and Bonhomme, 1987) that most of the folding and brittle tectonics which affect the Eastern Cordillera of central Peru, and was previously considered to be of late Cretaceous age ("Peruvian phase") by Mégard (1978), actually corresponds to a late Permian–early Triassic episode of compressive deformation.

The overthrusting tectonics of the Western Cordillera of southern Peru then appears as a completely specific feature of this area.

### *Sedimentological features*

To the north-northeast of the Arequipa overthrusting, Cordova (1985) and Noblet et al. (1987) show that the post-Cenomanian (or Santonian) filling of the Cuzco and Sicuani continental Red Bed foreland basins (Fig. 2) has been performed through constant inputs from the south-southwest; the topographic highs (corresponding with the present-day Western Cordillera) which supplied detritic sediments to the basin are demonstrated to have migrated progressively to the northeast. A synsedimentary compressive tectonics produced the progressive disconformity of the bottom of the Red Beds upon the tidalites of the underlying Yuncaypata formation (Cenomanian to Santonian), and progressive disconformities upon sinistral E–W wrench faults and NW–SE-trending synclines within the same Red Beds, with a north-northeast direction of compression.

In the Western Cordillera, the western part of the High Plateaus and the sub-Andean zone of central Peru, the transition is progressive between the upper Cretaceous marine formations and the conformably overlying Red Bed continental formation. In this area the base of the Red Beds appears as Santonian in age (Mégard, 1978). The same pattern is noted in northern Peru but there the base of the Red Beds is middle Campanian in age (Mourier et al., 1986). The base of the Red Beds formation then appears as diachronous from central Peru (Santonian) to northern Peru (middle Campanian), and the emergence does not correspond to a local tectonic event. As noted above, the Red Beds locally postdate a late Cretaceous deformation at the western edge of the Eastern Cordillera in the southern part of central Peru. In central and northern Peru, the conglomerates interbedded in the red silts and clays never constitute basal conglomerates. They may lie in slight disconformity over their substrate, and would indicate the jerks of uplift.

## Interpretative scheme

Our hypothesis is that the specific geological patterns detailed above may be related to the subduction and underplating of an anomalous feature of the oceanic crust such as a ridge or plateau, or an islands/seamounts volcanic chain some 80 Ma ago. Such an hypothesis (Figs. 3A, B and C) accounts for the cessation of magmatic activity by horizontalization of the slab and subsequent displacement of the fertile mantle wedge, as in front of the present-day Nazca ridge and the Juan Fernandez islands/seamounts volcanic chain. This allows the explanation of the observed overthrusting of the continental crust by local compression and the uplift of the Western Cordillera, which fed the Cuzco and Sicuani continental basins, by the isostatic re-adjustment subsequent to the thickening of the crust produced at one and the same time by the tangential tectonics and the underplating of the subducted ridge or plateau. The northeastward migration of the topographic

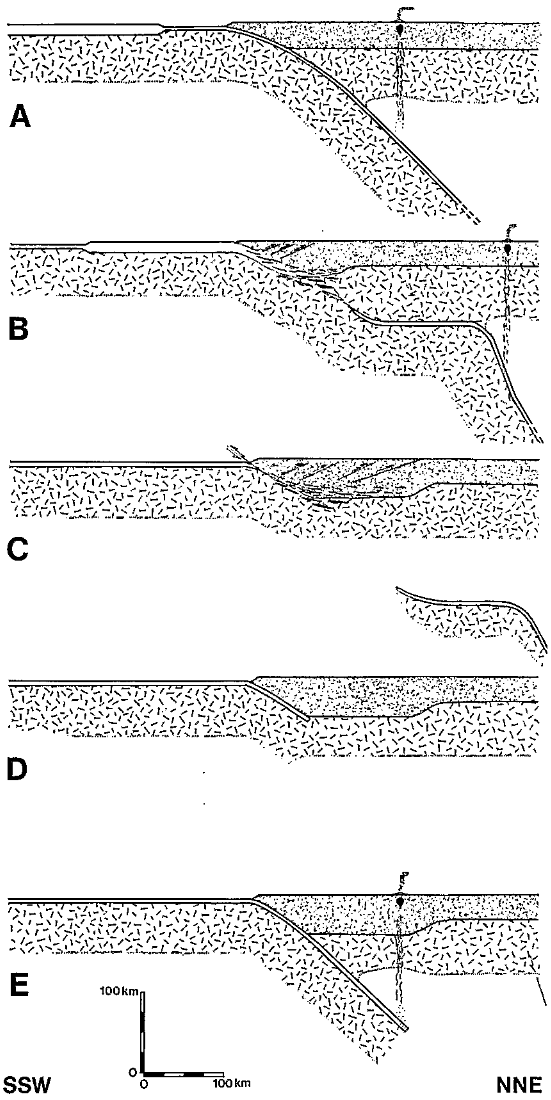

Fig. 3. Hypothetical evolution of the subduction geometry during the interval 84–70 Ma (stippled area—lithospheric mantle; shaded area—continental crust). A. "Normal" subduction prior to the arrival of the Mollendo ridge. B. Arrival of the Mollendo ridge. "Horizontalization" of the slab. Underplating initiates. Eastward displacement of the fertile mantle wedge. C. Underplating proceeds. Total rupture of the subducted plate. D. Initiation of a new subduction, with a geometry akin to A. E. Westward renewing of magmatic activity (≈ 70 Ma).

highs would correspond with the progressive underplating of the ridge.

Magmatic activity in the coastal region resumed after the rupture of the subducted plate, and the establishment of a new subduction with a geometry akin to that which prevailed before the subduction of the ridge or plateau (Figs. 3D and E).

The relative spatial distribution of the zone of magmatic quiescence, of the overthrusting and of the syntectonic Red Beds continental basins (Fig. 2) implies that this ridge, that we will henceforth call the "Mollendo ridge", has entered the subduction zone with an almost N–S direction (in a fixed South American reference frame) and that the anomalous feature of the slab had an E–W width of 300 km or more. These features permit the supposition that this anomalous feature was an oceanic ridge or plateau rather than an islands/seamounts volcanic chain.

Other hypothesis are possible, but all conflict with at least one of the late Cretaceous specific features of the South Peruvian margin.

A factor which may temporally prevent magma generation would be the accretion of an allochthonous terrain to the margin of southern Peru and northernmost Chile during late Cretaceous time. As a matter of fact, it has long been suggested that the Precambrian Arequipa massif (Dalmeyrac et al., 1977; Shackleton et al., 1979) of southern Peru may be an allochthonous terrain accreted to the western margin of the South American continent (James, 1971; Helwig, 1973; Kulm et al., 1977; Nur and Ben-Avraham, 1981). Actually, we cannot disregard this possibility but if so, the accretion of the terrain has occurred prior to the early Jurassic because subduction-related calc-alkaline volcanic and plutonic rocks, the ages of which give a continuous spectrum from early Jurassic (Chocolate volcanics; James et al., 1974) to late Cretaceous (Ilo and Tiabaya plutonic units; see above) overlie or intrude the suspect terrain. Then subduction has been continuous since at least the early Cretaceous and probably since the late Permian (Mégard, 1978, 1987), with a geometry akin to the present-day one. The (late Cretaceous) terrain hypothesis must then be rejected.

Another factor which may prevent arc magma generation would be a very low convergence rate between the Farallon and the South American plates, as assumed for the Oligocene magmatic quiescence period (Soler, 1987). The segment of late Cretaceous magmatic quiescence of southern Peru and northernmost Chile is bordered northward and southward by segments with continuous calc-alkaline, subduction-related, mantle-derived magmatic activity throughout this period (Cobbing et al., 1981; Aguirre, 1983, 1985; Pitcher et al., 1985). Then, convergence between Farallon and South American plates appears to have been effective all along the central Andes during this period and, if so, whatever the pole of relative rotation between the two plates could be, the longitudinal variation of the convergence rate has to be monotonous. In other terms, it is not conceivable that a low convergence rate segment would be bordered northward and southward by segments with a higher convergence rate. On the other hand, the tangential tectonics observed in the Arequipa region indicates a strong coupling between the Farallon and South American plates, in evident conflict with the low convergence rate hypothesis.

### *The identification of the mirror image of the Mollendo ridge in the Western Pacific*

We have shown that the Mollendo ridge was more probably an aseismic ridge or oceanic plateau than an islands/seamounts volcanic chain, and it may then be supposed to have been generated at or near a spreading centre (Pilger, 1981; Pilger and Hanschumacher, 1981; Cross and Pilger, 1982), which must be the paleo-East Pacific rise between the Pacific and Farallon plates, and to have an equivalent ("a mirror image") in the western Pacific Ocean.

On the basis of the present-day position of the magnetic anomalies in the southeastern Pacific (Herron, 1972) and of available reconstructions of paleodynamics of the Pacific Ocean (Larson and Pitman, 1972; Pilger, 1981, 1983; Whitman et al., 1983; Duncan and Hargraves, 1984; Pardo Casas and Molnar, 1987) and the Atlantic Ocean (Ladd, 1976; Sibuet and Mascle, 1978; Rabinowitz and

LaBrecque, 1979; Sibuet et al., 1984), the lithospheric age of the Farallon plate at trench level has been calculated using a step-by-step method. Considering a short step of calculation ($\Delta t$), convergence rates and directions may be considered as constants during every step. Then:

$$\mathrm{LAS}(t+\Delta t) = \mathrm{LAS}(t) + \Delta t\left[1 - \sin \Omega\left(V_{\mathrm{c}(t)}/V_{\mathrm{ac}(\mathrm{LAS}(t))}\right)\right]$$

where LAS($t$) is the Lithospheric Age of the Slab, $\Omega$ is the angle between the lineations of the magnetic anomalies and the trench elongation, $V_{\mathrm{c}}$ is the convergence rate at time $t$ perpendicular to the trench, and $V_{\mathrm{ac}}$ is the accretion rate at time LAS($t$) (the rate with which the plate subducted at time $t$ was created).

We made the calculation with a 1-Ma-long step, and the results of the calculation are reported in Fig. 4. The calculation indicates that the oceanic crust was young (between 15 and 55 Ma) at the trench in southern Peru some 80 Ma ago. However, the uncertainties are important, because the plate dynamics reconstruction for the late Cretaceous and the Palaeogene is poorly constrained for the existence of the late Cretaceous Quiet Period, the accumulation of uncertainties on previous reconstructions and for the absence of anomalies earlier than anomaly 23 which have already been subducted along the Andean margin. All the authors agree in considering that at 80 Ma the direction of convergence between the Farallon and South American plates was between N–S and NE–SW, in agreement with the geological arguments presented above. The subduction of the "Mollendo ridge" occurred during a period of high spreading rates of both the Pacific and Atlantic oceans, with the South American plate probably overriding the subduction zone as in the present-day situation (Minster and Jordan, 1978). The calculated lithospheric age, similar to the present-day one, in conjunction with the absolute trenchward motion of the continental plate, would imply a low angle of the Benioff–Wadati plane at this time, and would then be compatible with the hypothesis of "horizontalization" and underplating of the oceanic plate when and where the ridge is subducted.

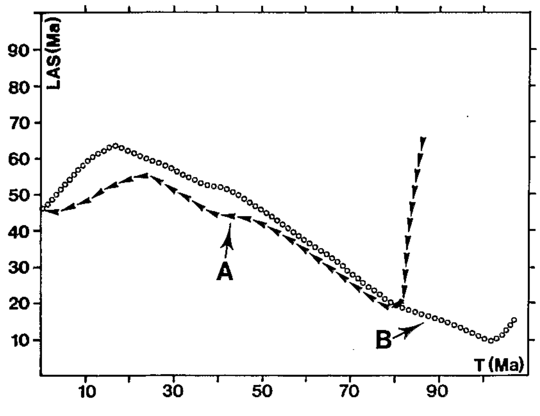

Fig. 4. Calculated lithospheric age of the oceanic crust at the trench in southern Peru some 80 Ma ago (method and references in the text). Curve *A* corresponds to a low spreading rate of the Pacific Ocean during the early Cretaceous; curve *B* corresponds to a high spreading rate during this epoch.

The calculated lithospheric age implies that if the "Mollendo ridge" has a mirror image in the western Pacific, this must be part of an oceanic crust created during the Lower Cretaceous (95–135 Ma B.P.) and will theoretically lie west of the Tuamotu within the Cretaceous Magnetic Quiet Zone, or the older part of the western Pacific. The Louisville ridge in front of the Tonga–Kermadec appears as a continuation of the Eltanin Fracture zone – Tharp Fracture Zone (Hayes and Ewing, 1971) and then lies in a over-south position to be a good candidate. To the north the only possible candidate appears to be the Manihiki plateau. Petrological and geochemical data on dredged samples (Winterer et al., 1974) and cores (Site 317, DSDP Leg 33; Jackson et al., 1976), and Sr- and Nd-isotopic data (Mahoney, 1989) suggest that the basalts from the Manihiki plateau were generated at a hot-spot influenced spreading centre (Jackson and Schlanger, 1976; Mahoney, 1989). Micropaleontological data (discussion and references in Jackson and Schlanger, 1976) and K–Ar dating (Lamphere and Dalrymple, 1976) show that this plateau was formed between 110 and 120 Ma ago. Both the age and the nature of the Manihiki plateau fit with the proposed model and the calculated lithospheric age of the slab detailed above. 80 Ma ago, the lithospheric age of the basalts of the "Mollendo ridge" would have been 30–40 Ma, which falls in the interval determined by calculation (15–50 Ma).

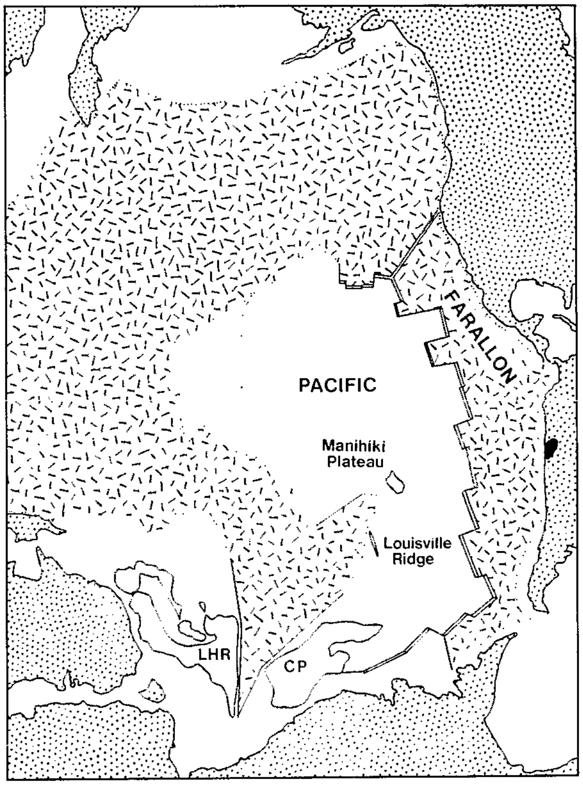

Fig. 5. Reconstructed geometry of plates in the Pacific region some 74 Ma ago (modified from Whitman et al., 1983). The stippled area represents the oceanic crust that existed at 74 Ma and has been subsequently subducted. Dotted area—continents (*LHR*—Lord Howe Rise; *CB*—Campbell Plateau). Double lines—active spreading centres; single lines—transform faults; dotted lines—subduction zones at 74 Ma and location of the present-day subduction zones rotated with the oceanic plates. The black area is the theoretical position of Mollendo ridge (mirror image of the Manihiki plateau) at 74 Ma. The western continental margin of South America has been considered as linear at that time (see discussion in text).

When considering plate reconstructions at 74 Ma (e.g. Whitman et al., 1983), the mirror image of the Manihiki plateau with respect to the Pacific–Farallon spreading centre lies exactly at the level of the Arica elbow, as predicted by the model (Fig. 5).

## Implications of the model

The proposed interpretation leads to a number of consequences that may help to improve our understanding of the late Cretaceous and subsequent evolution of the central Andes.

### *Magmatic implications*

The northern part of the area under considerations shows a very peculiar feature, i.e. the presence of the Andahuaylas–Yauri batholith (and associated Cu–Fe skarn-type deposits; Fig. 2) (e.g. Marocco, 1978; Santa Cruz et al., 1979; Noble et al., 1984; Soler et al., 1986; Carlier, 1989) the age of which is still unknown. Oligocene K–Ar ages (between 32.6 and 34.7 Ma) have been reported by Noble et al. (1984) on quartz-monzonitic porphyries associated with the Tintaya and Chalcobamba Cu skarn deposits; however, these porphyries are late with respect to the whole of the batholith (Carlier, 1989). Petrological and geochemical data (Carlier, 1989) show that this batholith is typically calc-alkaline and very probably subduction-related, but it lies some 150 km or more to the northeast with respect to the theoretical position that it would yield if the subduction had been "normal" in southern Peru at that time. In our hypothesis, which has to be confirmed by K–Ar dating (in progress in the University of Grenoble), the greatest part of this batholith would be late Cretaceous or early Palaeocene in age, and would be associated with the downgoing oceanic lithosphere in the front of the anomalous subhorizontal portion of the slab (Fig. 3B). The presence of calcic garnet, probably derived from the skarns associated with the batholith, within the upper Cretaceous Red Beds of the Cuzco basin (Carlier, 1989) supports our hypothesis.

The renewal of magmatic activity in the Arequipa region of southern Peru, which took place at ±70 Ma B.P., may be interpreted as a consequence of the development of a new oceanward subduction boundary (Figs. 4D, E) in accordance with the theoretical model proposed by Kelleher and McCann (1976). The short-lived distensive episode noted by Bussel and Pitcher (1985) in the Coastal Batholith of central Peru would be contemporaneous with the very moment of initiation of the new subduction, when the coupling at the interface would be at a minimum (Fig. 3D).

The implications of the proposed model upon the genesis of porphyry copper and skarn copper deposits in active margins will be discussed elsewhere.

### *Tectonic implications*

In addition to the Arequipa overthrusting, the strong coupling associated with the subduction and underplating of the "Mollendo ridge" with an N–S to N30° direction would produce dextral compressive wrench tectonics to the northwest of the affected area, and dextral distensive wrench tectonics to the southeast. Both effects have actually been observed. The model accounts for the dextral wrench faults observed in the Coastal Batholith in central Peru, near Lima (Bussell, 1983) and for the dextral wrench faults observed by Mégard (1978) and Marocco (1978) at the limit between the High Plateaus and the Eastern Cordillera to the northwest of the Andahuaylas–Yauri batholith in the Tambo – San Miguel area (Fig. 2). As a matter of fact, the synsedimentary normal faults that border the Altiplano basin (see for example the San Anton–Huancane–Moho fault described by Laubacher, 1978) and the change in the paleogeography of this area between the Turonian and the Campano-Maastrichtian (e.g. Laubacher, 1978) are in accordance with the structural patterns deduced from the proposed model.

### *The "Mollendo ridge" and the Bolivian orocline*

The area where the "Mollendo ridge" is supposed to have been underplated corresponds to the present-day Arica elbow and to the part of the Andes (Fig. 5) where the continental crust is the thickest (James, 1971; Cunningham et al., 1986). Of course, we do not mean that the overthickening of the continental crust in this area is due to the underplating of the "Mollendo ridge":

(a) Structural studies (e.g. Sébrier, 1987; Isacks, 1988) suggest that most of the tectonic deformation, the crustal thickening, and probably the formation of the Arica elbow took place during the past 45 Ma and, more particularly, during the past 25 Ma, with a E–W direction of convergence between the Nazca and South American plates.

(b) Paleomagnetic data (e.g. Kono et al., 1985; May and Butler, 1985; Beck, 1988) suggest that during the late Cretaceous the Arica elbow did not exist or was much less pronounced than today, i.e. the western margin of South America was more or less linear at that time, at least in the central Andes.

(c) Both the overthrusting tectonics in the continental crust and the underplating of the "Mollendo ridge" induced a late Cretaceous thickening of the crust in southern Peru and probably in northernmost Chile (Fig. 3).

Our hypothesis is that this thickened part of the margin will have a subsequent stronger coupling with the subducted lithosphere than the adjacent portions of the margin, and then will act as an "accumulation point" for the Andean deformations during the Cenozoic and, particularly, during the Neogene. We modestly assume that the underplating of the "Mollendo ridge" permitted the initiation of the observed differential Cenozoic tectonic thickening process along the Andean margin. The Bolivian orocline would then be at least partly a long-term consequence of the underplating of the "Mollendo ridge".

## Conclusions

It is obviously difficult to demonstrate unambiguously that the "Mollendo ridge" actually has existed and has been subducted and underplated during the late Cretaceous beneath the margin of southern Peru. However, the "Mollendo ridge" hypothesis has the value of explaining and linking various specific geological features of southern Peru, mainly:

(1) the gap in magmatic activity in the Coastal Range and the Western Cordillera between 84 and 70 Ma;

(2) the huge overthrusting faults involving the Precambrian basement in the Arequipa region;

(3) the abnormal eastern position of the Andahuaylas–Yauri batholith;

(4) the syntectonic filling of the Cuzco and Sicuani foreland continental basins.

Moreover, the supposed nature of the "Mollendo ridge", its calculated age, and the epoch and direction of its consumption and underplating lead to the assumption that the "Mollendo ridge" was an eastern equivalent of the present-day Mahiniki plateau of the western Pacific Ocean, and fit well with the available reconstructions of the dynamics of the Pacific Ocean.

Finally, the "Mollendo ridge" hypothesis contributes new elements to the interpretation of the Cenozoic tectonic evolution of the central Andes. In particular, it may be assumed that the Bolivian orocline would be at least partly a long-term consequence of the underplating of the "Mollendo ridge".

## Acknowledgements

We wish to acknowledge Th. Sempéré, A. Lavenu and Ch. Noblet for helpful discussions and, more particularly, H. Barsczus for supplying references on the Manihiki plateau.

This paper is a contribution of the UR F6 "Geodynamic and Mineral Concentrations" of the "Institut Français de Recherche Scientifique pour le Développement en Coopération—ORSTOM", which financed this research.

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