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The Hercynian basement: a review

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The foundation of the Mesozoic and Cenozoic Andes comprises Precambrian metamorphic rocks overlain by continental-derived clastics of Lower Palaeozoic age. The latter were converted into slates during an early Hercynian phase of deformation, eroded structures of which were covered by a molasse and shallow marine deposits during the Carboniferous. During the late Hercynian a mild, coaxial reactivation of the deformation introduced an episode of Permo-Triassic block-faulting and the deposition of a red-bed molasse, representing a transition from the compressive regime of the Hercynian to the extensional regime of the early Andean.

Introduction

Precambrian and Palaeozoic rocks crop out extensively in Peru south of 13° S along the coast, in the Western Cordillera, the Altiplano and the eastern Cordillera (Figure 4.1). Between 7° and 13° S these rocks are still widespread in the Altiplano and the Eastern Cordillera but are unknown in the Western Cordillera. Metamorphic rocks considered to be of Precambrian and/or Palaeozoic age occur in a few islands and in the Ballena offshore borehole (Figure 4.1). They are part of the outer shelf high that separates the shelf basins from the slope basins and ridges of offshore central and northern Peru (Thornburg and Kulm, 1981). North of 7° S, Precambrian and Palaeozoic rocks are again common in all the structural zones of the Peruvian Andes. It may thus be said that, with the possible exception of the coastal zone and Western Cordillera between 7° and 13° S, the Mesozoic and Cenozoic Andes are built upon a basement of Precambrian and Palaeozoic age.

Strictly speaking, the Precambrian basement is pre-Ordovician, since the first well-dated rocks overlying it are Ordovician in age. This basement comprises low to high-grade metamorphic rocks that belong mostly to a Brasilide orogenic belt about 600 Ma old. Older granulite facies metamorphic rocks occur along the borders of this belt (Figure 4.1). They are the large Arequipa Massif partly dated at about 2000 Ma (Cobbing *et al.*, 1977; Dalmayrac *et al.*, 1977) and the small Pichari Massif dated at about 1000 Ma (Dalmayrac *et al.*, 1980).

Most of the Palaeozoic rocks are sedimentary. The early and middle Palaeozoic strata were derived from continental areas mostly made of Precambrian sialic crust. They were deformed during the early Hercynian orogeny, which is late Devonian to early Carboniferous in age. With a few local exceptions metamorphism is either absent or of very low grade in the early Hercynian belt. Carboniferous and early Permian strata overlie this belt unconformably. They in turn were folded and faulted during the late Hercynian phase of Permian age that was relatively mild and did not cause metamorphism. It was followed unconformably by deposition of overlapping red beds and emplacement of volcanic and intrusive rocks during the late Permian and early Triassic.

In summary, with the exception of a few high-grade cratonic cores, like the large Arequipa Massif, the basement underlying the Mesozoic and Cenozoic Andean sedimentary and volcanic rock units comprises either metamorphosed or unmetamorphosed but frequently cleaved rocks, generally well-bedded and consisting of a high proportion of shales, slates and phyllites. Hence most of this basement is not rigid, but still able to behave in a ductile way during the Andean orogeny.

Sedimentation and magmatism in Cambrian to Devonian times

From the early Ordovician, and perhaps the Cambrian, to the late Devonian, a monotonous sedimentation of marine shales and sandstones took place in

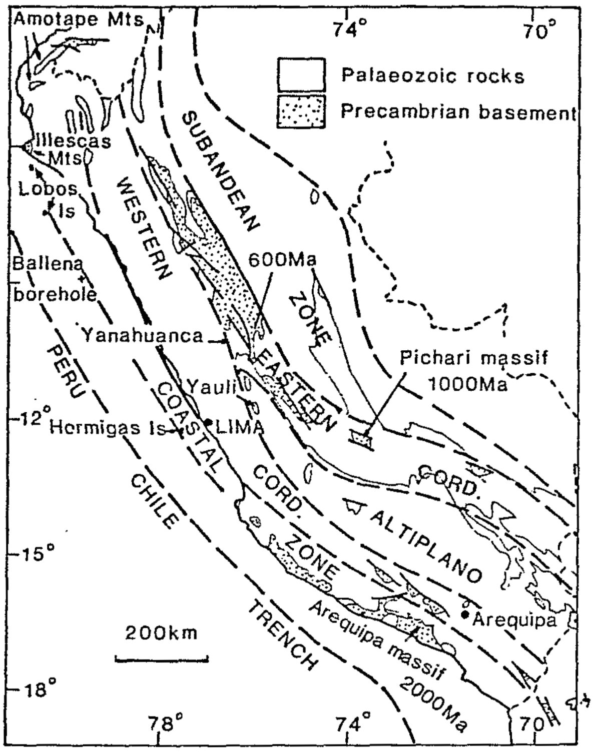

Figure 4.1 Sketch map of Peru showing the tectonophysiographic provinces and the main outcrops of Precambrian and Palaeozoic rocks.

a basin that probably covered all of Peru. Carbonates are very scarce and so are synsedimentary magmatic rocks. A 200–300 km wide NW-trending strongly subsiding trough (the Peru-Bolivia Trough) extended from Bolivia to central Peru (Figure 4.2). Its northern extension is not known as it is concealed by Mesozoic-Cenozoic units of the western Cordillera. Between 13° and 16° S a thickness of more than 10 000 m of early and middle Palaeozoic strata has been deposited along the

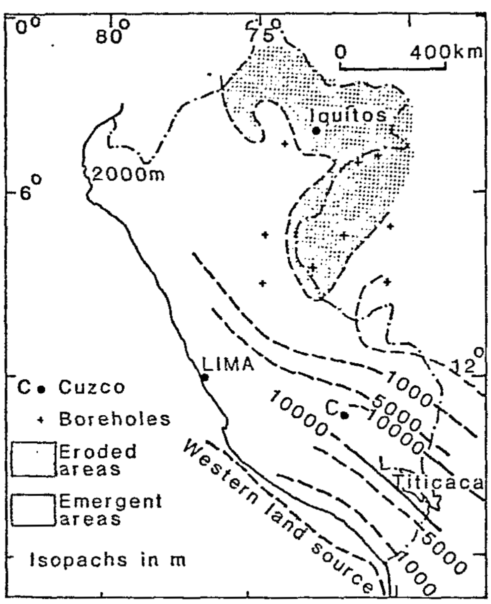

Figure 4.2 Isopach sketch map of early and middle Palaeozoic sediments. Isopach contours in metres, in broken lines when inaccurately defined. The appelation 'eroded areas' corresponds to areas where the Palaeozoic sediments have been eroded prior to deposition of unconformable Lower Cretaceous strata. Western land source according to Isaacson (1975).

axis of the trough. Sedimentation was continuous, except for a hiatus of Ashgillian age. Both to the NE and the SW of the trough, sediments are thinner and hiatuses related to partial regressions are common. The Arequipa Massif was the major south-western continental source area during the Ordovician (Laubacher, 1978), and the Silurian and Devonian (Isaacson, 1975). The Brazilian shield was emergent (Beurlen, 1970) but it is not known whether it was a major source area.

The Pre-Ordovician series in Peru

The oldest dated Palaeozoic strata known in Peru are Arenigian graptolite-bearing slates which outcrop north of Cuzco and conformably overlie a 300 to 400 m-thick conglomerate composed mainly of quartzite cobbles. This latter in turn rests disconformably upon quartzites and acidic welded-tuffs of the Ollantaytambo series (Marocco and Zabaleta, 1974) which is more than 1 km thick. Other pre-Ordovician volcaniclastic strata from an area 100 km east of Cuzco could be in part a time-equivalent of this series (Laubacher *et al.*, in press). Both are younger than the late Precambrian orogeny and may be Cambrian in age.

The Ordovician

In most places Ordovician conglomerates and quartzites lie unconformably upon Precambrian basement. They are in turn overlain by fossiliferous Arenigian or Llanvirnian strata. Black shales bearing graptolites and trilobites and a distal flysch series (up to 3000 m thick) made of alternating thin layers of shales and fine-grain sandstones were deposited during the Arenigian, the Llanvirnian and the early Caradocian (Bulman, 1932; Dalmayrac *et al.*, 1980) in the present eastern Cordillera between 13° and 15° S. Fossiliferous Llanvirnian shales have also been reported from the eastern Cordillera between 8° and 10° S (Lemon and Cranswick, 1956; Wilson and Reyes, 1964) and from the sub-Andean zone (Bulman, 1932; Davila and Ponce de Leon, 1971).

The late Caradocian series is a flysch sequence consisting of medium to coarse-grained sandstones and quartzites with a high sandstone/shale ratio. It is 3 to 4 km thick in the eastern Cordillera between 13° and 15° S and in the adjacent Altiplano NW of Lake Titicaca. Gravels are present to the southwest and denote the proximity of the Arequipa Massif source area. The Caradocian has also been identified in the sub-Andean zone but is only 0.5 km thick. In central Peru at 10° S, the fossiliferous mid-Ordovician shales are overlain by azoic quartzites of probably Caradocian age (Dalmayrac, 1978).

Rocks of early and middle Ashgillian age have never been identified in Peru nor in Bolivia. The sea withdrew from Bolivia at this time, and the Silurian strata overlie different parts of the Ordovician series disconformably (Martinez, 1980). In Peru, this event is recorded only by a widespread hiatus (Laubacher *et al.*, 1982).

Altogether, more than 7000 m of Ordovician strata were recorded in the eastern Cordillera from southern Peru (Laubacher, 1978) and northern Bolivia (Martinez, 1980). The thickness of Ordovician strata decreases both to the NE and the SW of the Peru-Bolivia trough. It seems that no Ordovician was deposited on the Arequipa Massif, with the dubious exception of the Marcona area (Figure 4.4).

The Silurian and the Devonian

Marine diamictite sediments correlative of the glacio-marine strata, called the Cancañiri and Zapla Formations in Bolivia and Argentina respectively, have been recognized 50 km to the north (Marocco, 1978) and 200 km to the east of Cuzco (Davila and Ponce de Leon, 1971). Their age is bracketed in Bolivia between the Caradocian and the late Llandoverian. In Peru they can be correlated with the basal strata of the Siluro-Devonian sequence from the Altiplano northwest of Lake Titicaca. This sequence comprises about 1 km of neritic sandstones and shales. The lower 600 m yielded fossils of latest Ashgillian to early Llandoverian age, and the upper 400 m, fossils of late Llandoverian to Ludlovian age (Laubacher *et al.*, 1982). 0.7 to 1.5 km thick quartzites, sandstones and conglomerates of latest Silurian and earliest Devonian age, overlain by more than 1 km of Emsian and Eifelian shales and sandstones, comprise the top of this Altiplano section. Scattered fossils found in the eastern Cordillera between 13 and 15° S (Laubacher, 1978; Marocco, 1978) date an undivided Siluro-Devonian sequence of shales, siltstones and sandstones more than 2.5 km thick.

The Devonian sea had a larger extent than the Silurian sea. Along the Peruvian Pacific coast, marine Devonian strata directly overlie the Arequipa Massif Precambrian basement west of Arequipa (Paredes, 1964; Boucot *et al.*, 1980). They are also known from the Amotape Mountains in northwestern Peru (Petersen, 1949; Martinez, 1970) and were identified at many places in central Peru (Harrison, 1943; Paredes, 1972) where they are at least 2.5 km thick.

Undivided early and middle Palaeozoic series

In central and northern Peru, many slightly or non-metamorphosed rocks which are strongly deformed and unconformably covered by late Palaeozoic rocks are ascribed to the early and middle Palaeozoic. Most are dark flysch-type series with alternating sandstones and siltstones. Rare limestones were reported from the Yauli dome (Figure 4.1). They are systematically associated with olivine-basalts and comprise irregular bodies up to some tens of metres thick, some of which are rich in crinoid stems (Harrison, 1943; Lepry, 1981).

Low-grade metamorphic rocks whose age is still a matter of controversy but which may be early or middle Palaeozoic crop out along the coast of southern Peru, around Marcona (Figure 4.3). They overlie a high-grade Precambrian basement and are intruded by the San Nicolas batholith dated at 392 ± 22 Ma

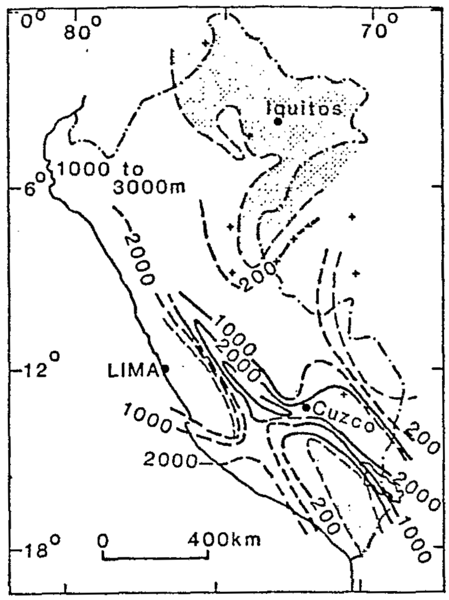

Figure 4.3 Isopach sketch map of Carboniferous and early Permian sediments. Legend as for Figure 4.2.

(Shackleton *et al.*, 1979). The low-grade metamorphics actually belong to two distinct series separated by an unconformity (Caldas, 1978). The lower series consists of a basal tilloid overlain by marbles with some metapelitic intercalations and is about 3000 m thick. The upper series comprises a basal conglomerate overlain by marbles about 1500 m thick. According to Shackleton *et al.* (1979), the age of the undivided low-metamorphic assemblages is bracketed between 440 ± 7 Ma, the age of the Atico igneous complex (Figure 4.1), and 392 ± 22 Ma, the age of the San Nicolas batholith, i.e. latest Ordovician to late early Devonian. In contrast Caldas (1978) has stated that the lower series is of late Precambrian age, and the upper one either late Precambrian or, more probably, early Palaeozoic. These series from the Marcona area are not easily correlatable with the early and middle Palaeozoic rock units from the Andes and nor are the metamorphic, deformational and plutonic events that affected them.

Early and Middle Palaeozoic magmatism

Scarce intercalations of volcanic rocks suggest that some volcanic activity was associated with the sinking Peru-Bolivia Trough. The occurrence of silicic tuffs in the pre-Ordovician Ollantaytambo series has already been mentioned. A few beds of redeposited quartz-bearing ashes are interspersed in Siluro-Devonian strata from the eastern Cordillera near the Peru-Bolivia border (Fornari *et al.*, 1982). Apart from the Yauli dome basalt flows, basaltic sills, some of which contain olivine, are present along the boundary between the sub-Andean zone and the eastern Cordillera in southern Peru. Locally they attain one-third of the thickness of the Silurian and Devonian strata. Because these sills have not been observed to cut Carboniferous strata they are considered to be Devonian in age.

The only granitoids emplaced during the early and middle Palaeozoic belong to the above-mentioned Atico complex and San Nicolas batholith.

The early Hercynian belt

In the eastern Cordillera the sediments deposited during the early and middle Palaeozoic were strongly deformed by the early Hercynian compression. Strong deformation is concentrated along the axis of the basin illustrated in Figure 4.2. In northern Bolivia and southern Peru, the early Hercynian belt is 200 to 250 km wide. It trends WNW but bends sharply at 17° S and strikes N–S farther south. To the north, in central Peru, it trends NW but its width is unknown, since its western part is concealed by the Meso- and Cenozoic units of the Western Cordillera (Figure 4.4).

The early Hercynian belt was eroded and overlain with a conspicuous angular unconformity by Mississippian clastics (Mégard *et al.*, 1971; Dalmayrac *et al.*, 1980). In the northwesternmost Eastern Cordillera of Bolivia this unconformity is bracketed by Frasnian and Tournaisian fossil-bearing series (Martinez, 1980). The K/Ar date of 346 ± 10 Ma from a post-tectonic adamellite in central Peru also gives a minimum age for the early Hercynian deformation (Maluski in Mégard, 1978).

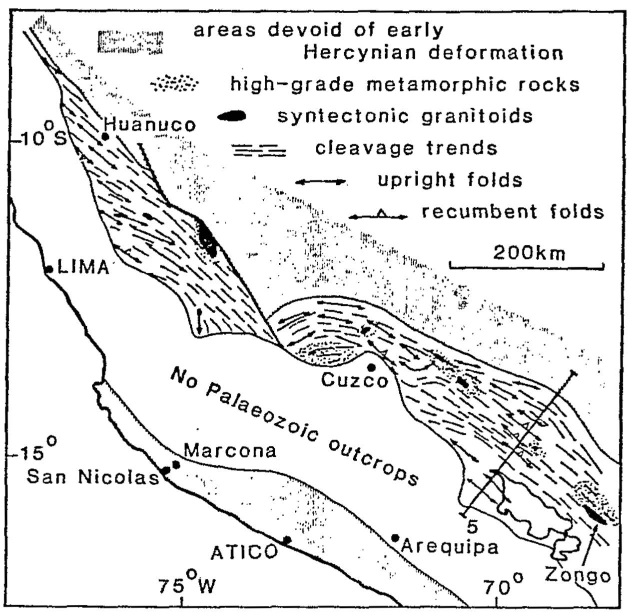

Figure 4.4 The early Hercynian belt in Peru and adjacent Bolivia, modified from Dalmayrac *et al.* (1980). Number 5 denotes location of the cross-section of Figure 4.5.

The best section across the early Hercynian orogen is a NE–SW section through southern Peru (Laubacher, 1978, and Figure 4.5). To the east in the sub-Andean zone the series of early and middle Palaeozoic age are flat-lying. In the Eastern Cordillera and Altiplano, the most conspicuous structures are N30° W to N80° W-trending folds and, commonly, a well-developed slaty cleavage. In the northeastern flank of the Eastern Cordillera, to the northeast the folds are open, upright and parallel and axial-plane cleavage is either absent or very coarse. To the southwest, they become tighter and change progressively to upright chevron folds with axial-plane slaty-cleavage. Large individual folds commonly have a wavelength of 1 to 3 km. The major structure is a 15 to 20 km-wide upright anticlinorium with a core of Lower Ordovician. Farther southwest, the folds become recumbent and southwest-vergent and are isoclinal near to the crest of the Cordillera. They are associated with large overthrusts that dip to the northeast with low angles. The intensity of the deformation decreases progressively across the Altiplano and near Lake Titicaca, only a few open parallel folds remain. All of these folds are F_1-folds. They are locally refolded by upright E–W to N40° W—trending small-scale F_2 folds associated with a vertical axial-plane strain-slip cleavage. Kink bands are also observed. The latter, and perhaps even the F_2 folds and S_2 cleavage, might be related to the late Hercynian folding. If it were extended farther SW, the section of Figure 4.5 would cross one of the two fossil-bearing outliers of Devonian rocks known in the Arequipa Massif. It comprises a broad open syncline that might be Andean or early or late Hercynian in age. Farther northwest in the Arequipa Massif, the Marcona Series, that is partly of early and/or middle Palaeozoic age, was strongly deformed. Two deformational and metamorphic events are recorded in the lower series, whereas only the younger events are observed in the upper series (G. Carlier, pers. comm.). Both of these events are older than the 392 ± 22 Ma old San Nicolas batholith and

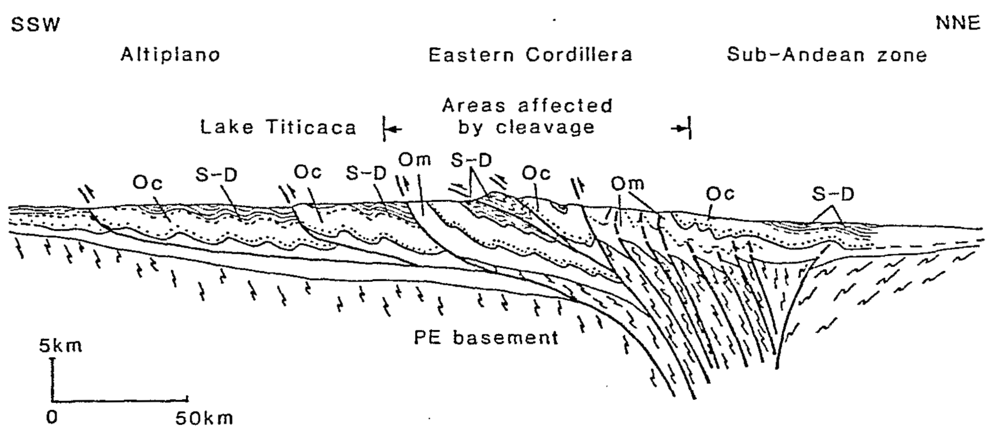

Figure 4.5 Cross-section through the early Hercynian orogen in southern Peru. The structures represented at depth are speculative. Location is given on Figure 4.4.

thus cannot be correlated with pulses of deformation and/or metamorphism known elsewhere in Peru.

In central Peru Palaeozoic rocks crop out discontinuously. This makes it impossible to reconstruct a complete section across the Early Hercynian orogen. Nevertheless, its structural zoning can be established from the sub-Andean zone to the Marañon thrust and fold belt of Tertiary age (see Mégard, 1984) that forms the northeastern boundary of the Western Cordillera. In the sub-Andean zone, the Carboniferous series lie conformably or disconformably over Devonian flysch (Martin and Paredes, 1977). The next outcrops to the west are located in the western part of the Eastern Cordillera and consist mainly of Devonian strata in which the most conspicuous structures are upright, approximately NW-trending F_2 chevron folds with wavelengths from less than a metre to some hundred metres and an axial-plane strain-slip cleavage S_2. They affect both the stratification and an S_1 slaty cleavage lying close to it. A few F_1 minor folds that trend roughly NE have been observed. Farther west, undivided early and middle Palaeozoic series outcrop in the Yauli dome (Figure 4.1). Prior to the Permian, they were also affected by both F_1 and F_2 phases of folding (Mégard, 1978; Lepry, 1981). The F_1 folds are similar to those of the eastern Cordillera. The F_2 folds are recumbent isoclinal, 10 to 200 m in wavelength and amplitude, and have a dominant N45°W-trend. S_2 dips either NE or SW with values near to 45°. Low dip inverted strata have been observed for about 8 km east of Yanahuanca, a village 135 km to the NNW of Yauli (Figure 4.1) in a flysch series ascribed to the early and/or middle Palaeozoic (Dalmayrac, 1978). They are associated with F_1 minor recumbent folds trending N40°W to N80°W that are NE to N-vergent. Minerals of the greenschist facies developed in the S_1 axial-plane cleavage. Both the strata and S_1 cleavage were refolded by F_2 N-S-trending upright folds associated with an S_2 fracture cleavage.

Metamorphism is generally of low-grade in the early Hercynian belt and is associated with F_1 folding. At some places higher-grade gneisses and schists, commonly bearing biotite, cordierite, andalusite or kyanite and rarely garnet and staurolite developed in country-rock surrounding syntectonic foliated biotite- and muscovite-bearing granitoids, like that of Zongo in northern Bolivia (Bard *et al.*, 1974). One of these granites, located 50 km north of Cuzco, yielded a 330 ± 10 Ma U/Pb age on zircons (Lancelot in Marocco, 1978).

Magmatism played a minor role in the early Hercynian belt as shown by the restricted number of syntectonic granite bodies and their relatively small sizes. The unique well-dated post-tectonic granitoid is an adamellite from central Peru, that is unconformably overlain by Mississippian clastic and volcanic rocks and yielded a K/Ar age of 346 ± 10 Ma on a biotite concentrate (Maluski in Mégard, 1978). Other post-tectonic granitoides may be present in the large and as yet undivided granitic batholith of the Eastern Cordillera north of 12° S.

Sedimentation and magmatism in late Palaeozoic times

The eroded structures of the early Hercynian belt are overlain with strong angular unconformity by late Palaeozoic sedimentary rocks. Most of them were deposited in continental or shallow-water environments. Flysch-type rocks were restricted to the most active subsiding troughs. Volcanic rocks are intercalated locally in clastic units of Mississippian and marine strata of Pennsylvanian age but the only widespread outburst of magmatism occurred during the late Permian and Early Triassic.

The late Palaeozoic sediments have been divided into four groups by Newell *et al.* (1953), which are, from bottom to top, the Ambo, Tarma, Copacabana and Mitu Groups, respectively of Mississippian, Pennsylvanian, early Permian and late Permian to early Triassic age.

The Mississippian series

The Mississippian Ambo Group is a molassic deposit related to the erosion of the early Hercynian mountain range. It is widespread in the eastern Cordillera between 7° and 17° S but is also present along the coast of southern Peru and in the Amotape Mountains in northwestern Peru. It has been encountered in boreholes in the sub-Andean zone between 13° and 17° S. In most places, it is a clastic continental assemblage with thin coal seams and it contains many plant remains. In the present Eastern Cordillera, the environment was paralic in a narrow NW-trending trough, as shown by marine intercalations (Wilson *et al.*, 1967; Mégard *et al.*, 1971). Greywackes are common in central Peru and may be related to the volcanic activity that gave rise to rhyolitic welded-tuffs and andesitic lava flows along the western border of the trough.

The Pennsylvanian series

The Tarma Group consists of terrigenous marine strata with carbonate intercalations, and, commonly, greywackes. It overlaps the Ambo Group, both east- and westward. In the sub-Andean zone, its base is a key-unit made of 100 to 400 m of bright blue-green greywackes overlain by shales and shallow-water fossiliferous limestones. A trough existed in part of the Eastern Cordillera, between 7° and 15° S, in which up to 3 km of flysch-like sediments accumulated capped by limestones. Its western limit is marked by the transition from shallow-marine to continental deposits. To the north and the east, the Eastern Cordillera Pennsylvanian basin was connected to the Amazon trough. To the south it was connected with a basin located in the coastal zone between 16° and 17° S. To the south-east, a gradual transition to Gondwanian continental facies is observed in Bolivia.

The early Permian series

A pulse of probable tensional deformation and subsequent erosion occurred at the end of the Pennsylvanian. Thus the Copacabana Group, in many localities, directly overlies early Palaeozoic rocks. It comprises shelf carbonates, interspersed with black shales and sandstones that together may reach up to 2000 m. At some places, they give way to sandstones and coal layers or to coarse-grained red sandstones and conglomerates. Fusulinids of Wolfcampian and early Leonardian age are common in the limestones. The Copacabana Group outcrops in the eastern Cordillera, the sub-Andean zone and the Amotape Mountains. The early Permian basin of Peru may still have been connected with the Amazonian trough.

The late Hercynian belt

During the late Leonardian, the early Hercynian belt was partly reactivated by the late Hercynian pulse of deformation. The resulting structures were subsequently eroded and unconformably overlain by the red terrigenous and volcaniclastic molasse interspersed with volcanic rocks of the Mitu Group, which was deposited during the late Permian and the early Triassic.

The late Hercynian pulse of deformation includes episodes of both folding and brittle tectonics that most probably have slightly different ages. The effects of the late Hercynian folding have been recognized in the southwestern flank of the Eastern Cordillera north of Lake Titicaca (Audebaud and Laubacher, 1969). The Carboniferous and early Permian strata are thrown into asymmetric NNW-trending chevron-folds with a wavelength of few hundred metres to a few kilometres, that are predominantly west-vergent and with which is associated an axial-plane fracture cleavage that locally grades into a slaty cleavage. This fold belt is only 80 km wide and 150 km long in Peru, but can be followed farther southeast in Bolivia. It disappears northwestward before reaching Cuzco. Late Hercynian N–S trending chevron-folds, associated with a steeply dipping fracture cleavage, have also been recently identified 250 km southwest of Lima in central Peru (Mégard *et al.*, 1983).

Both inside and outside the areas affected by this folding episode, late Hercynian block-faulting is active. Therefore, the Mitu molasse overlaps rock-units of different age in adjacent blocks. The late Hercynian faults are commonly vertical and many of them trend NW. They have large throws but horizontal movements also probably occurred.

Extensional block faulting went on during the late Permian and early Triassic, causing the Mitu molasse to have a very different thickness in contiguous blocks. Concurrently with molasse sedimentation a new magmatic regime appeared: for the first time during the Palaeozoic era large amounts of magma were emplaced in the present Eastern Cordillera and in the Altiplano. Volcanic rocks are commonly andesites, but both peralkaline rhyolites and subalkaline basalts were also erupted which are typical of an extensional regime, either in a back-arc or a rift environment (Noble *et al.*, 1978). In the eastern Cordillera large granitoid bodies were intruded (Capdevila *et al.*, 1977; Lancelot *et al.*, 1978; Carlier *et al.*, 1982), which are discussed in greater detail in Chapter 5 of this book. In terms of these unique features, late Permian and early Triassic times appear as transitional between the Hercynian and the Andean periods.

Concluding remarks

The main structural event of the Palaeozoic era is clearly the early Hercynian orogenesis. Its nature is still enigmatic. The Peru-Bolivia basin of early and middle Palaeozoic age appears to be an ensialic basin. No island arc of this age has been identified. No suture has yet been discovered in the fold belt. It was tempting to assume that the Arequipa Massif was an exotic block that might have collided with or 'docked' against the continent (see Nur and Ben-Avraham, 1981) and caused either the Hercynian or Andean orogeny. However, the first results of a paleomagnetic investigation performed on a Devonian outlier on the Arequipa Massif and on Devonian series near Lake Titicaca tentatively suggest that no latitudinal displacement occurred between both since Devonian times (Knight *et al.*, 1983). The stresses that caused the Peru-Bolivia trough to be compressed at the end of Devonian and/or during the early Mississippian were probably transmitted by the rigid Arequipa block and originated along its western borders. Subsequently, this western border has probably been tectonically eroded along the Cenozoic Peru-Chile trench or its Mesozoic forerunner. Alternatively the western border may have been sheared by transcurrent faulting and shifted horizontally, or rifted and then accreted at a distant place.

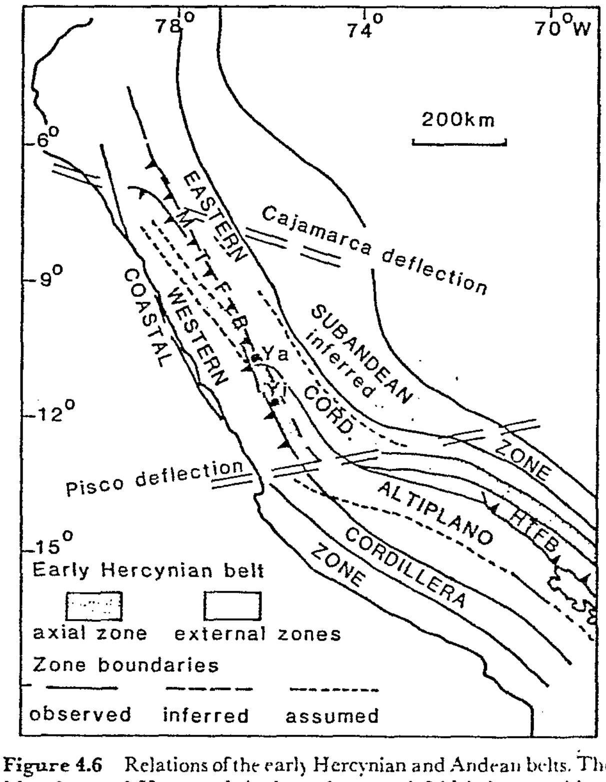

Figure 4.6 Relations of the early Hercynian and Andean belts. The Marañon and Huancané Andean thrust and fold belts are abbreviated to MTFB and HTFB. Yi, Yauli; Ya, Yanahuanca.

In southern Peru, the early Hercynian belt is restricted to the Eastern Cordillera and the Titicaca Altiplano. It forms the basement of these Andean physiographic and structural units and was obviously reactivated during the Andean orogeny. In particular, the basement under the Andean Huancané thrust and fold belt (Figure 4.6) consists of Palaeozoic rocks that belong to the axial zone of the early Hercynian belt; the unusual SW-vergence of the Huancané belt might be related to the reactivation of an early Hercynian flat thrust of the same vergence. The whole of the western part of the Western Cordillera is built upon the rigid Precambrian Arequipa Massif, that has been sheared at low-temperature along flatly SW-dipping thrusts during the Andean orogeny in the region to the NW of Arequipa (Vicente *et al.*, 1979).

North of 13° S, the early Hercynian belt appears to have been shifted westward. In particular, strongly deformed rocks belonging to its axial zone occur very close to the Andean Marañon thrust and fold belt of the western Cordillera (Figure 4.6). If we assume that the early Hercynian belt is as wide in central Peru as in southern Peru, and if we take into account the fact that this belt is slightly oblique to the grain of the Peruvian Andes (Figure 4.4) we may logically conclude that it forms a major part of the basement of the Western Cordillera between the Pisco and Huancabamba deflections (Figure 4.6). It is the contention of one of the present authors (Mégard, 1984) that the Andean shortening of the Meso-Cenozoic cover in the Marañon fold and thrust belt and in the strip characterized by chevron-folds and located immediately west of it, was absorbed at depth mainly by plane-strain in the still ductile Hercynian basement. At least part of the difference in tectonic style in the Andes north and south of the Pisco deflection might be explained by differences in the composition and resulting ductility of the basement of the Western Cordillera.

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MAGMATISM AT A PLATE EDGE

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