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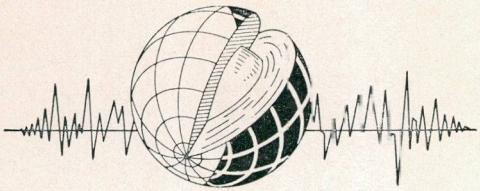

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LIMINARY AND GEOSYNCLINE ANDES: MAJOR OROGENIC PHASES AND SYNCHRONICAL EVOLUTION OF THE CENTRAL AND AUSTRAL SECTORS OF THE SOUTHERN ANDES [1]

by
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ABSTRACT

The classical opposition between the different types of organization and evolution of the Liminary Central Sector and the Geosyncline Austral Sector of the southern Andes is a result of two aspects of the same remarkable Andean orogenic system along the Pacific margin of the South American continent (Fig. 1).

A comparison of the tectonic evolutions and of the principal orogenic phases of both sectors shows a remarkable synchronism of the major orogenic pulsations. It is however necessary, in establishing a comparison, to regard the distinction between the internal and external zones and to compare them with one another correspondingly. These tectonic phases because of the characteristic polarity of the chain are older in the internal zones where the orogenic wave starts, and younger in the external zones, where this wave dies out.

From the comparison of the synthetic stratigraphical columns it is possible to distinguish five tectonic phases which were determined on direct (unconformities) and indirect evidences (syntectonic intrusions and sedimentology).

These are:

Upper Jurassic (Kimmeridgian)
Middle Cretaceous (Albian-Turonian)
Upper Cretaceous (Maastrichtian-Lower Paleocene)
Lower Tertiary (Upper Eocene-Oligocene)
Upper Tertiary (Upper Miocene)

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Their orogenic or tectogenic character is discussed when enough data are available.

Appart from the fundamental differences between these sectors, like the predominance of continental series in the liminary Andes and of marine series in the geosynclinal sector, it is concluded that both regions had a parallel and synchronic geotectonic evolution which demonstrates the major unity of the Andean chain.

RESUMEN

La oposición clásica entre los tipos de organización y de evolución del Sector Central Liminar y del Sector Austral Geosinclinal de los Andes del Sur argentino-chilenos traduce dos aspectos del notable sistema orogénico andino desarrollado en el margen occidental del continente sudamericano (Fig. 1).

Al establecer una comparación entre las evoluciones tectónicas de ambos sectores se evidencia una estrecha sincronía entre las pulsaciones orogénicas y fases tectónicas mayores, a condición de respetar la distinción entre zonas internas y zonas externas y de confrontarlas separadamente. Como consecuencia de la polaridad característica del edificio los acontecimientos son, en efecto, sistemáticamente más antiguos en las zonas internas, punto de partida de las ondas orogénicas, que en las zonas externas, punto de llegada de estas mismas ondas.

El análisis y la comparación de las columnas estratigráficas sintéticas respectivas permite reconocer en el margen occidental del continente cinco fases tectónicas fundamentales evidenciadas tanto directamente (discordancias) como indirectamente (intrusiones sintectónicas y sedimentología) durante el:

Jurásico superior (Kimmeridgiano)

Cretácico medio (Albiano-Turoniano)

Cretácico superior (Maastrichtiano - Paleoceno inferior)

Terciario inferior (Eoceno superior - Oligoceno)

Terciario superior (Mioceno superior)

La importancia de estas fases como generadoras de montañas (orogénesis sensu stricto*) o como generadoras de estructuras (tectonogénesis) es discutida.*

Se concluye de este modo, haciendo abstracción de las diferencias fundamentales, como el predominio de depósitos continentales en el Sector Liminar y de depósitos marinos en el Sector Geosinclinal, una evolución geotectónica paralela y sincrónica de ambos sectores, que evidencia la constitución unitaria mayor del edificio andino.

Introduction

In the Chilean-Argentinian portion of the Southern Andes it is posible to oppose two different sectors on the basis of their organization and evolutionary types during the Andean orogenic cycle (Mesozoic-Tertiary-Quaternary): the Central Sector with liminary characteristics and the Austral or Patagonian Sector with geosyncline characteristics (AUBOUIN y BORRELLO, 1966 and 1967; BORRELLO et AUBOUIN, 1970; VICENTE, 1970a) (Fig. 1).

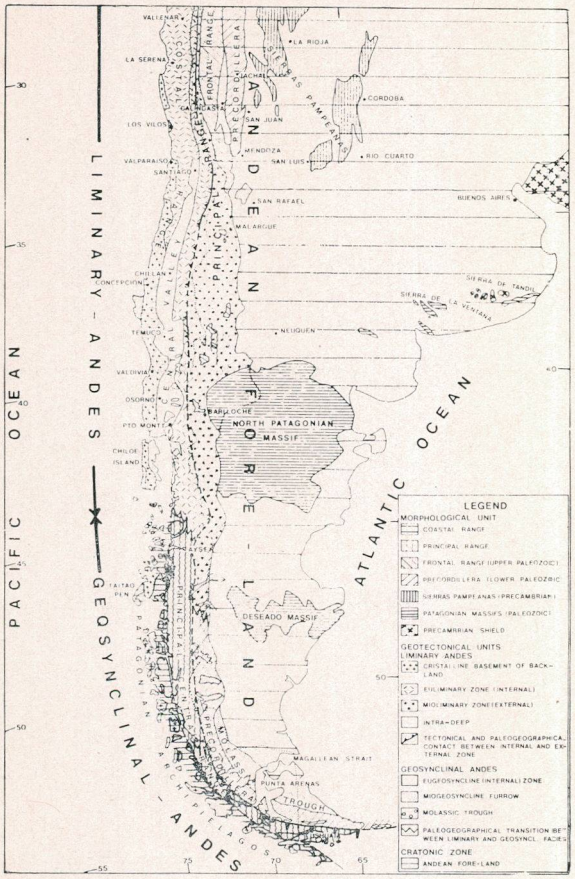

Fig. 1: Morphological and geotectonical units of the southern Andes.

This opposition reflects a gradual transition towards the south from a pericontinental position (*sensu stricto*) of the Central Sector to the intercontinental position (between the Patagonian and Antarctic Cratons) of the Austral Sector (VICENTE, 1970a). This transition however does not alter the remarkable continuity of the oriental peripacific system at its meridional portion.

We will try to demonstrate with an analysis of the major orogenic phases that this orographic continuity is the result of a similar tectonic evolution.

In effect, these phases have a remarkable synchronism in both sectors provided that the fundamental distinction between internal (to the W) and external (to the E) zones is respected and that the homologue zones are compared one with another.

Under major orogenic phases will be understood those phases evidenced by structural unconformities or great stratigraphical discontinuities or by characteristic terrigene accumulations.

The Central Liminary Sector

I. The major morphostructural and paleogeographical divisions

The major morphostructural units of this sector have a typical N-S orientation.

Between the parallels 31° and 35° S. lat. it is possible to distinguish from W to E, or from the Pacific Ocean to the South American cratonic foreland which is presently covered by the sediments of the Argentine Pampa, four units (Fig. 1):

1) A *Coastal Range,* along the Pacific, corresponding fundamentally to an occidental Paleozoic axis with a backland signification. On its oriental versant lie unconformably thick Mesozoic volcanic series which are characteristics for the Andean Cycle.

2) A *Principal Range* constituting the boarder chain between Chile and Argentina with Mesozoic and Tertiary series. It is possible to distinguish and oppose a volcanic-volcanodetritic occidental versant, and a sedimentary oriental versant (AUBOUIN y BORRELLO, 1966 and 1967; VICENTE, 1970a) (Fig. 2).

3) A *Frontal Range* which corresponds to a second Paleozoic (upper) axis. On the occidental versant of this range transgrede the Mesozoic series of the Principal Range.

4) A *Precordillera* developed to the N of Mendoza which forms a third Paleozoic (lower) axis.

Thus, regionally the whole Andes Range seem to be a large hanging sinclinorium constituted by the Mesozoic and Tertiary deposits of the Principal Range and the E versant of the Coastal Range inserted between two basement anticlinoriums: the Coastal and Frontal Ranges.

These major morphostructural units are thus clearly the result of a compressive basement folding of the occidental rand of South America retouched by a normal faulting (N-S; E-W) responsible for the present division in horsts and grabens (VICENTE, 1970a and b).

The comparison of the synthetic stratigraphical columns of the Coastal Range with those of the oriental versant of the Principal Range brings out, for the Andean Cycle, a fundamental asymmetry between an occidental volcanic and volcano detritic domain and an oriental sedimentary domain (Fig. 2). This is the classical contrast between internal and external characters respectively of the pericontinental orogenic chains (AUBOUIN y BORRELLO, 1966 and 1967; VICENTE, 1970a and 1970b).

The paleogeographic transition between the internal (to the W) and the external (to the E) zones takes places aproximatively along the Chilean-Argentinian boundary (*divortia acquarium*) and is evidenced by the "major andean tectonic thrust" (VICENTE, 1970b) which favors a certain thrusting of the internal zones over the external series.

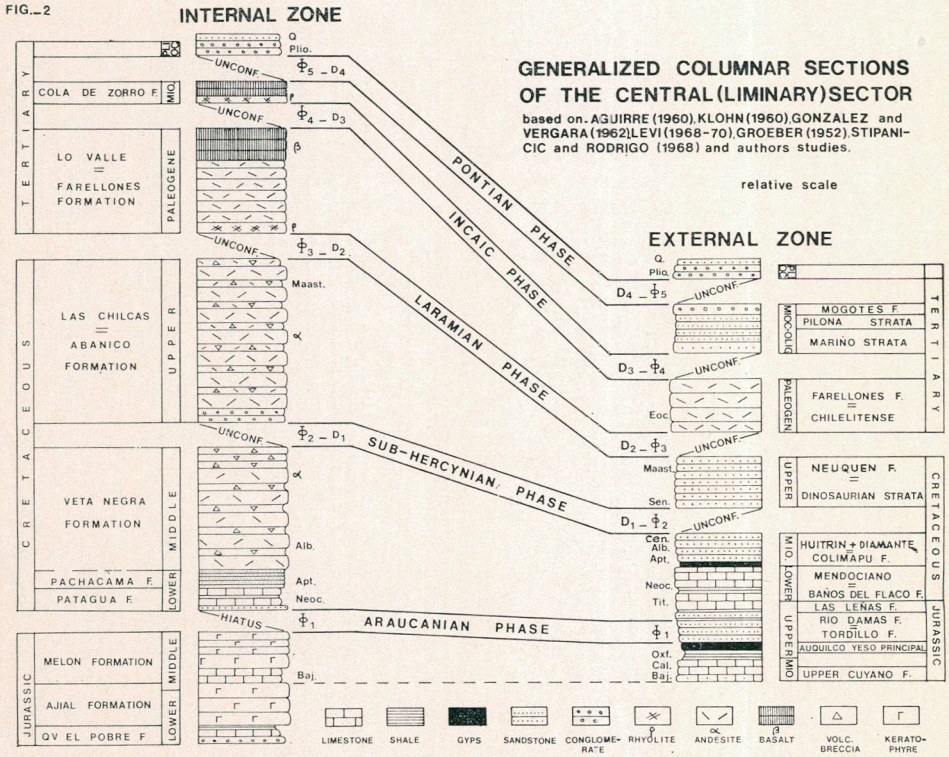

Fig. 2: Generalized columnar sections of the central (liminary) sector.

Besides this opposition the external zone corresponds to a trough (mioliminary) while the internal zone behaved like an instable ridge (euliminary) (VICENTE, 1970b).

II. Major orogenic phases

1) *The Araucanian or Kimmeridgian Phase:* Preliminary to this phase took place a marine regression at the end of the Oxfordian Stage with an extensive deposition of evaporites ("Yeso Principal") in the external trough. This phase caused a general emmersion of the whole liminary domain and is evidenced by:

   a) a stratigraphic hiatus in the Upper Jurassic (essentially during the Kimmeridgian) along the Coastal Range. No unconformity has been observed (THOMAS, 1958).

   b) very thick conglomeratic deposits during the Kimmeridgian in the Principal Range (KLOHN, 1960; AGUIRRE, 1960; GONZALEZ and VERGARA, 1962; GONZALEZ, 1963; CHARRIER, 1970; DAVIDSON y VICENTE, 1970). The regular decrease in thickness of the series and coarseness of the sediments toward the E strongly suggests that the provenance area of these conglomerates lay to the W. Carboniferous granitic and Triassic rhyolitic pebbles from the basement and volcanigenic Lower Mesozoic materials of the most internal zones like queratofires (Neotriassic-Eojurassic) and Upper Jurassic andesites to which these conglomeratic deposits grade, support this origin (CHARRIER, 1970; VICENTE, 1970b; DAVIDSON y VICENTE, 1970).

   The thickness and size of the pebbles at the "internal-external paleogeographic transition" demonstrates the intensive erosion of occidental positive reliefs during a relatively short time (Kimmeridgian), since the sea transgreded again already in the Lower Tithonian over this continental masses (KLOHN, 1956; THOMAS, 1958; CORVALAN, 1959; CHARRIER, 1970; DAVIDSON, 1971).

   This orogenic phase which affected only the most internal or occidental zones (Coastal Range) produced no unconformity but only a hiatus of the Upper Jurassic (THOMAS, 1958): the marine Tithonian transgreded directly over the Middle Jurassic. In northern Chile this phase caused a clear angular unconformity described by CECIONI (1961 and 1970), CECIONI and GARCIA (1960) and GARCIA (1967) which evidences the existence of a Kimmeridgian tectogenetic phase.

   Associated to this phase took place the first Andean granodioritic plutonic cycle (RUIZ *et al.*, 1960; LEVI *et al.*, 1963; RUIZ *et al.*, 1965) which consolidated the most internal zones in a continuous N-S band along the Coastal Range.

A first burial metamorphic phase reaching the green schists facies affects the Lower and Middle Jurassic formations of the Coastal Range (LEVI, 1969 and 1970). Even though the metamorphic facies are, according to Levi, essentially parallel to stratification, an thus, considered pretectonic, the repetition of burial methamorphic episodes associated to each major stratigraphical-structural units relates these episodes closely to the major orogenic phases, thus the possibility of an E-W gradation in this region from strict burial metamorphism to regional metamorphism as in eastern Australia (SMITH, 1969) is not dismissed by the present authors.

2) *The Subhercynian or Albo-Senonian Phase:* This phase is also announced by a regression at the end of the Neocomian (the last of the Andean Orogenic Cycle) and is recognized by the general unconformable position of the Upper Cretaceous volcanic and volcano detrictic series over older formations:

   a) in the Coastal Range (LEVI, 1969 and 1970; AGUIRRE y THOMAS, 1964) where a thick basal conglomerate (Las Chilcas F., Viñita F.) covers unconformably the Aptian-Albian volcano detritic series (Veta Negra F. and Quebrada Marquesa F.).

   b) in the Principal Range (KLOHN, 1960; VICENTE, 1970a and 1970b; DAVIDSON, 1971) where the Upper Cretaceous volcanic formations (Coya-Machalí and Abanico) lie unconformably on the Aptian-Albian (MARTINEZ y OSORIO, 1963) red conglomeratic and sandy deposits (Colimapu F.) intensively folded in characteristic anticlines with gypsum cores.

   The thick conglomerates generated by this phase, croping out on the occidental versant of the Principal Range evidently correspond to the destruction of the thick andesitic series of the most internal zones. They show a gradual decrease in thickness and granulometry toward the E and grade finally to a few hundred meters red continental sandstones on the oriental margin of the external trough or the W versant of the Frontal Range.

   This facies tansition to the E suggest that first the coastal region was transformed by the orogenesis in an active mountain range predominantly constituted by volcanics which, while being eroded, supplied detritic materials to an orientally situated foredeep. This foredeep was at its turn uplifted and deformed but only after its filling. From this it is clear that the deformation of the more external zone took place later than in the internal zone (coastal region). It is suggested that the migration of the orogenic wave is responsible for this retardation.

   This extensively distributed phases is related to the second late tectonic Andean granodioritic plutonic cycle (RUIZ *et al.*, 1960; LEVI *et al.*,

1963) which constituted a N-S striking band shifted to the E of the precedent intrusive stripe.

A second burial metamorphic phase reached the green schists facies at the bottom of this second stratigraphical-structural unit which comprises Lower and Middle Cretaceous formations of both the Coastal and Principal Ranges (LEVI, 1970).

This Subhercynian Phase, considered to be one of the major tectoorogenetic phases of the Andean Cycle, is also responsible for the thrusting of the internal series over the external series along the "palogeographic transition zone" (VICENTE, 1970b).

3) *The Laramian or Late Cretaceous-Early Tertiary Phase:* This phase is essentially recognized in the Principal Range and along the oriental versant of the Coastal Range.

The andesitic-basaltic and rhyolitic Early Tertiary formations (Lo Valle-Farellones) lie in clear unconformity (KLOHN, 1960; AGUIRRE, 1960; JAROS and ZELMAN, 1969; CHARRIER, 1970; VICENTE, 1970a and 1970b; MARTINEZ, oral com.) on older series and more particularly on the Cretaceous andesitic sequence (Las Chilcas-Abanico F.) definitively dated by the recent discovery of dinosaur bones (CASAMIQUELA *et al.*, 1969). The intensive folding affecting the Abanico F. along the paleogeographic "internal-external zones transition", which is situated on the back of the "major tectonic thrust", contrasts with the ample folding style of the immediately younger Farellones F. and evidences a tectogenectic phase at the end of the Cretaceous-the beginning of the Cenozoic. This phase corresponds to the second major tectogenetic phase responsible for the major thrusting of the volcano-sedimentary internal series over the sedimentary external series and the scale ("écaillage") of the mio-liminary sedimentary cover in the eroded "Subhercynian" anticlines with gypsum intrusions.

A third granodioritic plutonic cycle related to this orogenetic phase (RUIZ *et al.*, 1960; LEVI *et al.*, 1963) constituted a N-S trending band also, shifted to the E of the precedent granitic stripe since it intruded the W versant of the Principal Range.

A third burial metamorphic phase (LEVI, 1969 and 1970) affected the upper Cretaceous formations and also reached slightly the green schists facies at the bottom of this third stratigraphic-structural unit, without retromorphosis on the previously metamorphosed series.

This orogenic phase is dated only indirectly by means of the radiometric ages of the granodiorites. Its regional extention is reduced to the Principal Range. Along the Pacific coast an epicontinental sedimentation took place during the Upper Cretaceous and Lower Tertiary on the back-

land in the Arauco-Concepción, the Chanco and the Algarrobo regions (BRUGGEN, 1915; CECIONI, 1970; CHOTIN, 1970).

4) *The Incaic or Upper Eocene-Lower Oligocene Phase:* The existence of this phase is demonstrated along the occidental or Chilean versant of the Range and especially in the southern portion of the considered area by the angular unconformity which separates the Early Tertiary volcanic Farellones F. from the Miocene volcanic Cola de Zorro F. (GONZALEZ y VERGARA, 1962; VERGARA, 1970; THIELE and KATSUI, 1969). Its age however is difficult to establish because the exact age and the time duration of the Farellones F. are unknown.

The age here accepted for this phase is therefore only a proposition and is that of the same phase in the Austral or Magellan Sector. A similar phase in Peru has an Upper Eocene age (MEGARD, 1967).

A fourth postectonic granodioritic plutonic cycle (RUIZ *et al.*, 1960; LEVI *et al.*, 1963) around 30 m.y. closely related to this phase would mark an immediately succesive relaxation phase and would thus date the phase to the Late Eocene-Early Oligocene.

A fourth and last burial metamorphic phase (LEVI, 1969 and 1970), which reached only the zeolite facies, affects the lower Tertiary formations of the east versant of the Costal Range and of the Principal Range.

5) *The "Pontian" or Upper Miocene Phase:* This phase is clearly represented in the most external portion of the Andes: Frontal Range, Precordillera and Pampean Range, where Paleozoic basement blocks are clearly thrusted over Oligo-Miocene red continental series (AUBOUIN y BORRELLO, 1966; BORRELLO et AUBOUIN, 1970).

This phase is likewise responsible for the compressive basement folding which deformed the Andean basement and individualized the major actual orographic units: Coastal Range, Frontal Range and Precordillera anticlinoriums, and to the NE the Sierras Pampeanas.

As a result of this phase big mountainous masses were emplaced (PASKOFF, 1970) which only were retouched by essentially Lower Pliocene and also Upper Pliocene-Lower Quaternary fracturations (Villafranchian) (VICENTE, 1970a).

It must be stressed that this phase affected preferently the more external zones of the Andes and even the foreland and therefore could be denominated the "external zones phase". These external zones were thus for the first time much later deformed than the more internal zones showing clearly the polarity of the orogenetic wave.

In the west versant of the Principal Range, its effects can however be recognized in the ample fold structures of the rhyolitic and andesitic-basaltic Miocene Cola de Zorro F. (GONZALEZ y VERGARA, 1962).

Accompanying this phase an acidic subvolcanic plutonism with a microgranite to dacitic character was emplaced. This plutonism corresponds to the fifth Andean tardi-tectonic plutonic cycle (VICENTE, 1970a) of Late Miocene age (15-10 m.y., BORRELLO, oral com.). These intrusions form a still more external band than the older plutonics which followed roughly the structural limits between internal and external liminary zones. Isolated intrusions can also be found as far to the East as the Precordillera.

III. Conclusions

From this analysis of the Central Liminary Sector five major orogenic phases are evidenced, the effects of which are only partially superposed in reason of the progressive eastward migration of the orogenetic axis with time. The effects of the Araucanian Phase are thus concentrated to the Coastal Range (the most internal zones) while the Subhercinian Phase embraced both the Coastal and the Principal Ranges and the "Pontian" Phase reached the foreland and was restricted to the most external zones.

Regarding the relative importance of the different phases, the tectogenetic effects of the Subhercynian Phases must be emphasized. The structures formed during this phase were retouched with a decreasing intensity by the Laramian and the Incaic Phases, resulting from this a "major Andean thrust" at the paleogeographic transition between the volcanic internal (W) and sedimentary external (E) series of the Principal Range. The "Pontian" Phase followed with its fundamental orographic consequences.

The Austral Geosynclinal Sector

I. The major morphostructural and paleogeographical divisions

The Austral or Patagonian Sector corresponds to the southern portion of the Chilean-Argentine Andes south of 48° S. lat. This Sector is characterized by the remarkable convexity of its structures toward the Pacific Ocean and thus contrasts with the rectilinear structures of the Central Sector. This convexity is also reflected in the orientation of the morphostructural units which grade, between the 48° and the 52° S lat., from a N-S to an E-W orientation. In Tierra del Fuego begins the Scotia Arc which in turn has an opposite convexity (toward the Atlantic Ocean) (Fig. 1).

From W to E, or what is the same, from the Pacific Ocean to the Patagonian Foreland (South Patagonian or Deseado Massif) it is possible to distinguish three fundamental morphostructural units (Fig. 1):

1) *The Patagonian Archipelago:* which includes the labyrinth of fjords and islands along the Pacific margin. This unit is constituted to the W by a strip of Paleozoic geosyncline deposits and to the E by a complex of syncinematic anatectic granites associated to its oriental side essentially

S of the 53° S. lat., to metamorphosed sediments of the eugeosincline vacuity (KATZ, 1964; DALZIEL and CORTES, 1970). At some localities the granitic domes overthrust the sedimentary series (KATZ, 1964; BORRELLO, 1969).

2) *The Patagonian Range:* which orographically prolonges the Principal Range of the Central Sector and is constituted by:

a) an occidental strip with eugeosyncline vacuity sediments of the Yaghan F. (Upper Jurassic-Lower Cretaceous): graywackes and siltstones with radiolaritic intercalations and some flysch-like sediments at its upper part associated to a synsedimentary andesitic and basaltic vulcanism (pillow-lavas). The sediments are in different parts of the Range strongly metamorphosed and thrusted to the E (and to the N in Tierra del Fuego) (KRANCK, 1932; KATZ, 1964; KATZ and WATTERS, 1966; DALZIEL and CORTES, 1970) and are also associated to syncinematic anatectic granites.

All cited characteristics for this strip are typical for internal geosynclinal domains and more exactly for eugeosynclinal troughs.

b) an oriental strip with Paleozoic metamorphic rocks wich were uplifted by the thrusting of the internal over the external zones (the acidic volcanic Tobífera F.). This Tobífera F. thrusts also at some localities the shaly vacuity sediments of the external trough or miogeosyncline but is generally covered conformably by these sediments.

This oriental strip of the Patagonian Range may correspond to an old paleogeographic element, the miogeoanticline ridge which is presently uplifted by the thrust faults.

The pronounced and repeated thrusting is oriented eastward in the N part of the Range but is oriented northward in Tierra del Fuego where it reaches its maximum intensity.

3) *The Precordillera* (along the oriental side of the Patagonian Range) corresponds to most of the miogeosyncline external trough and is by far the best known region of the Austral Sector (GONZALEZ *et al.*, 1965).

This external trough has also a curved orientation and its internal margin is intensively thrusted toward the external domain while its external margin gently rest on the border of the cratonic Deseado Massif.

Here again the comparisons between the synthetic stratigraphic columns of the occidental versant of the Patagonian Range (east margin of the eugeosyncline trough) clearly evidence the characteristic contrast between internal and external domains as well as the typical polarity of the pericratonic ranges even when in Magellanes the internal domain is still rather unknown (Fig. 3).

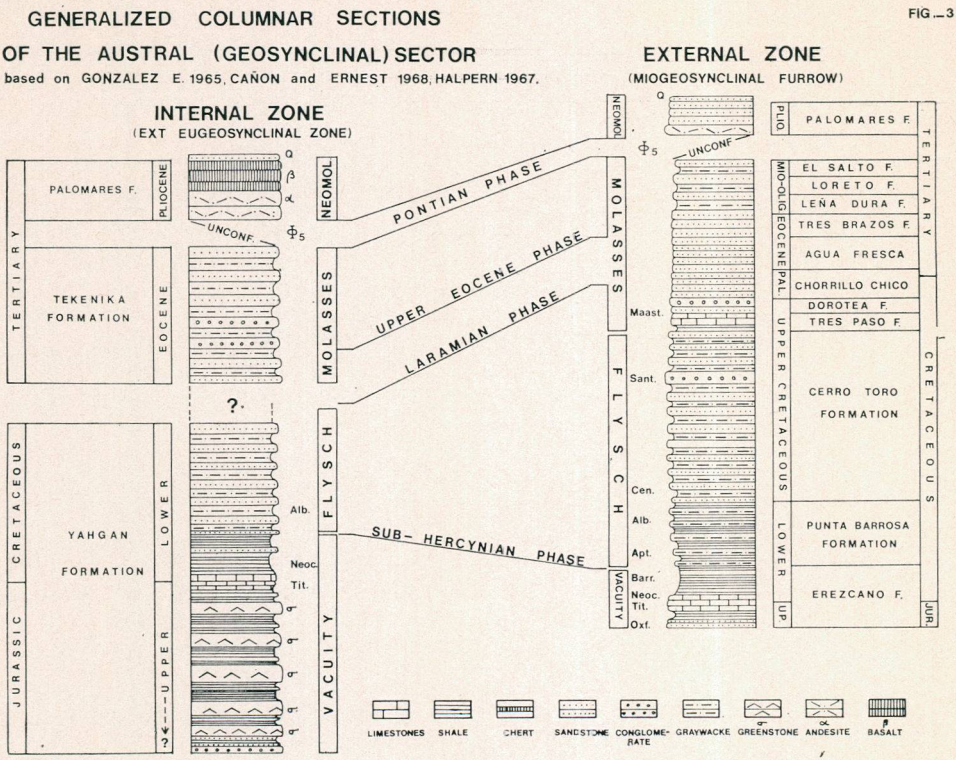

Fig. 3: Generalized columnar sections of the austral (geosynclinal) sector.

II. Major orogenic phases

Direct as well as indirect evidences for the older orogenic phases are completely unknown. The reason for this is the little geological knowledge and the structural complexity of the internal zones, which is the domain where generally the older orogenic phases are especially well developed.

1) *The interrogative of the Upper Jurassic Phase:* The late individualization during the Upper Jurassic (CECIONI, 1955; MARTINEZ y ERNST, 1965; SIGAL, 1967) of the external trough did not allow evidences for this phase, even if indirect, to be registered. However:

   a) the direct deposition of the internal Upper Jurassic-Lower Cretaceous Yaghan F. (HALPERN, 1967) on Paleozoic schists and the absence of of the rhyolitic Triassic-Jurassic Tobífera F. widely developed to the East suggest its possible erosion in the internal zones.

b) the presence in the Yaghan Formation of intermediate and basic volcanic fragments (KATZ and WATTERS, 1966) suggest also the erosion of some positive relief in the more internal zones. The presence of basement pebbles (CORTES, oral com.) would confirm this conclusion.

These indirect arguments are however not definitive and it is necessary to emphasize that they were observed in the non metamorphosed Yaghan F., which correspond to the external margin of the eugeosyncline since the more internal facies of it were completely obliterated by the intensive plutonism and metamorphism which even anatectized this sediments.

2) *The Subhercynian or Albo-Santonian Phase:* This is the first important phase which is clearly determined. The available evidences are however indirect except for an unconformity localy observed at Dawson Island by CECIONI (1960) and fundamentally the very thick detritic conglomeratic and Flysch series (Punta Barrosa and Cerro Toro Fs.) deposited in the external trough from Albian to Santonian times (CECIONI, 1957 and 1970; ZEIL, 1958; KATZ, 1963; CORTES, 1964; SCOTT, 1966). Following CECIONI (1957 and 1970) the maximum intensity of this phase was reached during the Turonian. In Tierra del Fuego, however on the external margin of the miogeosynclinal furrow a Cenomanian to Santonian hiatus is registered (CORTES y VALENZUELA, 1960).

The increase in thickness and abundance of Upper Cretaceous conglomeratic levels to the west (CECIONI, 1960; CORTES, 1964); the presence of rhyolite crystalline schists, greenstones, quartz, biotite, granites, foliated sedimentary rocks among the pebbles of the Upper Cretaceous conglomerates (CECIONI, 1957 and 1960; ZEIL, 1958; CHARRIER and LAHSEN, 1969); the heavy mineral assemblages and the oligoelement content of the fine fraction of the sediments (CHARRIER and LAHSEN, 1969) and the slump and flow structure analysis (CORTES, 1964; SCOTT, 1966) demonstrate the presence of a mountain range to the west of the external trough affected by an intensive erosive process.

The internal zone was thus being uplifted since the Albian and constituted the "Paleoandes" (CECIONI, 1957 and 1960). This mountain range was the source of the thick sedimentary deposits which filled the miogeosyncline.

In the internal zones this intensive phase caused:

a) an intensive regional metamorphism which remobilized the schists and gneisses of the socle and affects the sedimentary Yaghan F. on the westernmost regions (HALPERN, 1962; KATZ, 1964; WATTERS, 1965) and is associated to syncinematic granites present along the west versant of the Patagonian Range (KATZ, 1964).

b) an intensive thrusting and even overthrusting of syncinematic anatectic granitic domes over more external sedimentary series (KATZ, 1964; BORRELLO, 1969).

c) the development during the Upper Cretaceous of unconformably tardigeosynclinal volcanic molasses (Tekenika F.) (intradeep?).

d) a first known plutonic cycle with a K/Ar age of 77 ± 5 m.y. and a Rb/Sr age of 82 ± 3 m.y. (HALPERN, 1962 and 1967) intruded along the axis of the Patagonian Range.[4]

Contemporaneously with that of the Central Sector a burial metamorphic phase prehenitized the Yaghan F. at Navarino Island (WATTERS, 1965).

The Subhercynian tecto-orogenetic phase is remarkably complete and is the major for the internal domain. The age can be, according to the delay between the sedimentation of the Flysch series and the tectogenesis, considered Albian-Santonian.

3) *The Laramian or Late Cretaceous-Early Tertiary Phase:* This phase remained essentially concentrated to the Patagonian Range where it prolonged the effects of the Subhercynian Phase.

No direct evidences have been observed in the Patagonian Range and in the Precordillera. In this last region CHARRIER and LAHSEN (1968 and 1969) evidenced by means of structural, sedimentological, paleoecological and geochemical criteria a completely gradual transition from the Upper Cretaceous to the Lower Tertiary series.

This phase is however evidenced by:

a) an eastward and northeastward migration of the axis of the cretaceous miogeosyncline trough;

b) a gradual upheaval and a consequently gradual transition from marine to continental facies in the Maastrichtian-Paleocene series of Ultima Esperanza. A regresive process (Chorrillo Chico F.) which gradually progressed towards the south, and at the same time to the east, and which ended in southern Tierra del Fuego in the Upper Miocene (CHARRIER and LAHSEN, 1968 and 1969; LAHSEN and CHARRIER, 1971);

c) the unconformity involving a Paleocene hiatus between the Upper Cretaceous and the Lower Tertiary on the E margin of the trough (cratonic platform) in the Springhill District (GONZALEZ *et al.*, 1965);

d) the first folding of the pre-Paleocene series of the Precordillera in Tierra del Fuego, in the front of the Flysch thrusting;

4 The Subhercynian Orogeny, according to the Commission on Geochronology of the IUGS (1966), took place 80 m.y. ago.

e) the second plutonic cycle which was dated at 63 ± 10 m.y. (Pb alpha on an adamellite sample) by LEVI *et al.* (1963) and averaged by HALPERN (1967) at 65 ± 6 m.y. from three Rb/Sr analysis on morainal boulders from the Alemania Glacier in the Darwin Range (Tierra del Fuego);

f) a second regional metamorphic cycle dated at 64,2 ± 1,2 m. from analyses of late crystallized muscovite porphyroblasts from paraschists supposedly related to the Yaghan F. and the northward thrusting of this unit (Yendegaia Bay) (HALPERN, 1967).

The Laramian Phase affected thus, almost exclusively the internal domain where it corresponds to the second major tectoorogenetic phase. The Precordillera registered only a migration of the axis of the trough.

4) *The Incaic or Upper Eocene-Lower Oligocene Phase:* In the Precordillera between Skyring Sound and the Strait of Magellan the Late Cretaceous to Eocene Formations have the same tectonic style (CHARRIER and LAHSEN, 1965). They were thus deformed late in the Eocene or during the Lower Oligocene since younger formations are milderly deformed. This is also an evidence for the strict internal character of the Laramian Phase and the more external character of this first phase of the Tertiary.

KATZ (1962) concludes from a tectonic analysis of the Ultima Esperanza region that the Late Cretaceous formations were buried under a sedimentary cover which attained an Eocene age when deformed for the first time. This same author (1962) cited for a still more external region an unconformity between Maastrichtian units and Oligocene and even Lower Miocene conglomerates and sandstones.

A third intrusive cycle can be deduced from the 37,8 ± 1,6 m.y. K/Ar age (Early Oligocene) of hornblendes from garnetiferous amphibolite cut by quartzose veins which are exposed near the contact of the Patagonian Range intrusives (HALPERN, 1967).

5) *The "Pontian" or Upper Miocene Phase:* This phase is essentially restricted to the more external regions and is responsible for the major tectogenesis of the Tertiary late tectonic series accumulated in the molassic foredeep and the important thrust faulting in the Precordillera of Tierra del Fuego (CORTES y VALENZUELA, 1960).

With this phase the emmersion of the Austral Sector which began to the N during the Late Cretaceous-Early Tertiary, comes to definite completion. This emmersion and the consequent unconformable accumulation of continental post-tectonic molasses (Palomares F.) evidence that this phase has in this region the same orographic character it has in the Central Sector.

A last plutonic cycle resulted in a series of relatively small intrusives of which the well known quartz monzonitic laccolith Cerro Paine was dated at 12 ± 2 m.y. by HALPERN (1967), an age which corresponds to the Late Miocene to Early Pliocene.

III. Conclusions

The analysis of the evolution of the Austral Geosynclinal Sector permits to recognize four major orogenic phases essentially synchronic with the last four phases of the Central Liminary Sector. Even when the greater complexity due to the geosynclinal characteristics of this sector greately difficults interpretation, the effects of this four phases clearly evidence a migration through time of the orogenetic wave towards the external domain.

As a result of this migration the Sub-Hercynian Phase affected only the Patagonian Archipel and the Patagonian Range and the Laramian Phase concentrated to the latter affecting the Precordillera only on its internal margin. The Incaic and the "Pontian" Phases are restrictec to the external domain.

In relation to their relative importance the Subhercinian Phase, because of its tectogenetic and metamorphic effects, is the principal for the internal zones while the "Pontian" Phase has the greater importance for the external zones especially in relation to its orographic effects which were fundamental for the building of the actual Cordillera.

Conclusions on the Synchronism of the Orogenic Phases

Because of the relatively complete regional knowledge of the Central Liminary Sector it is possible to build a clear scheme of its orogenic evolution. The Austral of Patagonian Geosynclinal Sector is still very partially known, except for the external trough which has been systematically surveyed in search for oil; its internal domain in turn is almost unexplored.

It was however possible in this analysis to find in this Austral Sector, except for the Araucanian Phase, which, if present, has to be searched in the more internal zones, the four other major orogenic phases known in the Central Sector. Even though the most of them were recognized with indirect evidences all were typically individualized permiting therefore an immediate comparison of the evolutions of both external domains, liminary and geosynclinal respectively: more precisely the phases that affected the oriental versant of the Principal Range, the Frontal Range and the Precordillera in the Central Sector are the same that affected the Patagonian Precordillera.

Because of the orogenic polarity to compare the older phases both internal zones must be compared one with another.

With the present state of knowledge a remarkable synchronism of the major orogenic phases is evident for both the Central Liminary and the Austral Geosyncline Sectors. This synchronism or parallel tectonic evolution of the southern portion of the Andes explains the tectonic and orographic continuity of the chain.

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