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A GEOLOGICAL SECTION ACROSS THE HESPERIAN MASSIF IN WESTERN AND CENTRAL GALICIA[1]

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ABSTRACT

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A section across the axial zone of the northern Hesperian massif in Galicia is presented. It is extrapolated to a depth of 5 km on the basis of gravity data obtained over key areas near Mellid and Santiago de Compostela.

Several lithotectonic units are distinguished in this part of the massif. Lower Palaeozoic supracrustals, closely associated with late Palaeozoic migmatites, granitic and metamorphic rocks constitute the regional tectonic framework. Infracrustal rock complexes occur in subcircular to elongate outcrops. Those representing the higher basement levels are of mesozonal metamorphic grade and contain abundant amphibolites and calcalkaline as well as peralkaline granite gneisses. Others, representing the lower basement levels, are predominantly catazonal and have prominent constituents of the continental upper mantle. Some of the latter are associated with dismembered meta-ophiolites of Palaeozoic age. For the evolution of the northern Hesperian Massif a mantle-plume/rift-system model is preferred. An outline of this model is provided.

INTRODUCTION

Western and central Galicia comprise the axial zone of the northern Hesperian massif, as the Variscan orogenic belt of the Iberian peninsula is commonly denominated (Fig. 1). It consists mainly of a central culmination flanked by marginal geoclinal troughs or basins in eastern Galicia and south-western Portugal. Thick sequences of Late Proterozoic and Palaeozoic sediments and volcanics have accumulated in the latter environments, whereas the central zone is characterized by incomplete and reduced sequences of Early Palaeozoic and by the absence of Late Palaeozoic and Mesozoic supracrustal formations.

Tertiary deposits are restricted to local depressions in the basement. An infra-Cambrian volcanodetrital molasse deposit, known as Ollo de Sapo, constitutes an antiformal belt between the eastern Galician basin and the central zone, indicating substantial uplift and erosion of a regionally developed Precambrian granitic crust long before the onset of the Variscan orogeny.

The axial zone contains an abundance of granitic rocks and migmatites ranging in age from late Ordovician to early Permian. The earliest of these have been transformed into metamorphic orthogneisses, the later ones have only been deformed or retrograded to various extents. Some granitic rocks are clearly post-tectonic. The remainder of the axial zone is made up by rocks with metamorphic histories of variable complexity. Those with the longest metamorphic histories are restricted to a number of fault-bounded inliers viz. the blastomylonitic graben, the peripheral belt of the Ordenes basin, the Lalin/Forcarcy unit, and the Cabo Ortegal complex. In previous papers by members of the Leiden research group the latter rocks have been called polymetamorphic. It is still maintained that their metamorphism is polyphase or plurifacial (DE ROEVER & NIJHUIS, 1963). But it will be clear from the following paragraphs that there is little conclusive evidence for metamorphism resulting from the superposition of two orogenic cycles as required by READ's (1949) definition of polymetamorphism. For further information on Galician and northern Portuguese geology the reader is referred to PARGA PONDAL (1966), DEN TEX (1966), MATTE (1968), CAPDEVILA (1969), DEN TEX & FLOOR (1971), RIBEIRO (1974), ARPS ET AL. (1977) and DEN TEX (in press).

The geological cross-section (Encl. I) is the integrated re-

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sult of approximately twenty years of detailed mapping, geophysical surveying and laboratory work carried out by members of the Research Group 'Galicia' in the State University at Leiden. The trace of the section is indicated on the map sheets Finisterre-Santiago and La Estrada, and (on a reduced scale) on the present index map (Fig. 2) Subsurface extrapolation to a depth of 5 km is based on gravity models obtained for the Mellid and Santiago complexes (KEASBERRY, 1979). The section will be published simultaneously in full colours, as part of a series of eight geological maps, a legend sheet and explanatory text by the Geological and Mineralogical Institute of the State University at Leiden[3].

LITHOTECTONIC UNITS

Eight lithotectonic units may be distinguished in western Galicia (DEN TEX, 1966, 1979) two of which consist predominantly of supracrustal igneous and metamorphic rocks while the others are inliers containing considerable amounts of infracrustal rocks and upper mantle material. The latter group will be dealt with comprehensively.

The Late Palaeozoic migmatites, granitic and metamorphic rocks

In the northern Hesperian Massif two main types of Late Palaeozoic granitic rocks are recognized (CAPDEVILA & FLOOR, 1970; FLOOR, 1970; FLOOR ET AL., 1970; CAPDEVILA ET AL., 1973): (1) Predominantly biotite-bearing calcalkaline granites and granodiorites with a subcalcic plagioclase (An_{10-40}) and (2) predominantly two-mica-bearing alkaline granites carrying albite or oligoclase (An_{0-20}).

The first type is rarely, if ever, associated with granitic migmatites, pegmatites, quartz veins and ore mineralizations of any kind. In Galicia some of these granitic rocks were intruded immediately before or during, others after the fourth deformation phase (F_4). The earlier ones are locally associated with leucocratic microgranites and with tourmaline-, garnet- or beryl-bearing aplites.

The second main type of granite frequently grades into granitic migmatites and is abundantly associated with pegmatites, quartz veins and Sn-, W-, and Li-mineralizations (YPMA, 1966; HENSEN, 1967; HILGEN, 1970). It is almost exclusively (par-)autochthonous and was emplaced between F_3 and F_4. Rb-Sr whole-rock isochron ages have been determined at 311 ± 21 Ma for the alkaline and calcalkaline granites, and at 297 ± 11 Ma for the post-F_4 calcalkaline granites (PRIEM ET AL., 1970; VAN CALSTEREN ET AL., 1979). These Late Palaeozoic granitic rocks and migmatites are distributed widely throughout the axial zone of the northern Hesperian massif but they occur rarely within the infracrustal inliers. In the area of the cross-section a western is separated from a central granite-migmatite complex by the Ordenes basin and its peripheral belt. The earlier calcalkaline granites display a distinct preference for fundamental faults, such as the boundary faults of the blastomylonitic graben (DEN TEX, 1977), while the later calcalkaline granites frequently form composite bodies of subcircular disposition or concentrical outcrop.

The Late Palaeozoic migmatites grade from inhomogeneous granites into a wide variety of metamorphic rocks ranging from ortho- and augengneisses to paragneisses and pelitic micaschists. Metatexitic and diatexitic stages can be recognized in the development of the migmatites, while restites of quartzite, calcsilicate rock and amphibolite are locally present. Their protolith was undoubtedly a mixture of Precambrian and Early Palaeozoic rocks subjected to Late Palaeozoic metamorphism. This metamorphism can be distinguished from earlier high-pressure events by its low- to intermediate-pressure facies series involving porphyroblastic chlorite, biotite I & II, garnet, staurolite, andalusite I & II, sillimanite and cordierite in frequently plurifacial prograde sequences in (semi-)pelitic rocks (DEN TEX & FLOOR, 1971; HILGEN, 1971; VAN MEERBEKE ET AL., 1973; MINNIGH, 1975; ARPS ET AL., 1977; BUISKOOL TOXOPEUS ET AL., 1978).

Apart from the late development of andalusite II in contact with some postkinematic calcalkaline granites, the metamorphic progradation is bracketed almost entirely by F_3 and F_4. Corroded relics of a pre-existing garnet occur in rocks of the infracrustal inliers only, and are generally restricted to inclusions in second-generation garnet or plagioclase. However, rocks in which the Late Palaeozoic metamorphic imprint is paramount, are relatively rare within the infracrustal rock complexes.

The Early Palaeozoic supracrustal rocks

In westernmost Galicia the presence of Early Palaeozoic supracrustal rocks is based on lithostratigraphic correlations only, no identifiable fossils having been found in the sediments. Radiometric age determinations are not available, mainly on account of the widespread metamorphism of the eruptive rocks involved.

(Semi-)pelitic schists with quartzose or feldspathic laminae, white and black quartzites, anthracite schists, amphibolites, calcsilicate rocks and iron-rich horizons occur mainly south of the Ria de Muros y Noya in a submeridional belt near the Atlantic coast. This belt continues into N. Portugal where A. RIBEIRO (1974) has reported fossils with Cambrian to Silurian ages for the various formations involved. Similar but rather less variable rock types are found in the central Galician schists area between Forcarey, Lalin, Carballino, and Avion.

Further to the NE anchi- to low-grade metamorphic supracrustal rocks of Ordovician and Silurian ages have been identified in the NW limb of the Barquero antiform (MATTE,

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[3] Prices and details of ordering and payment may be obtained from the Librarian, Geologisch en Mineralogisch Instituut der R.U., Garenmarkt 1b, LEIDEN, The Netherlands.

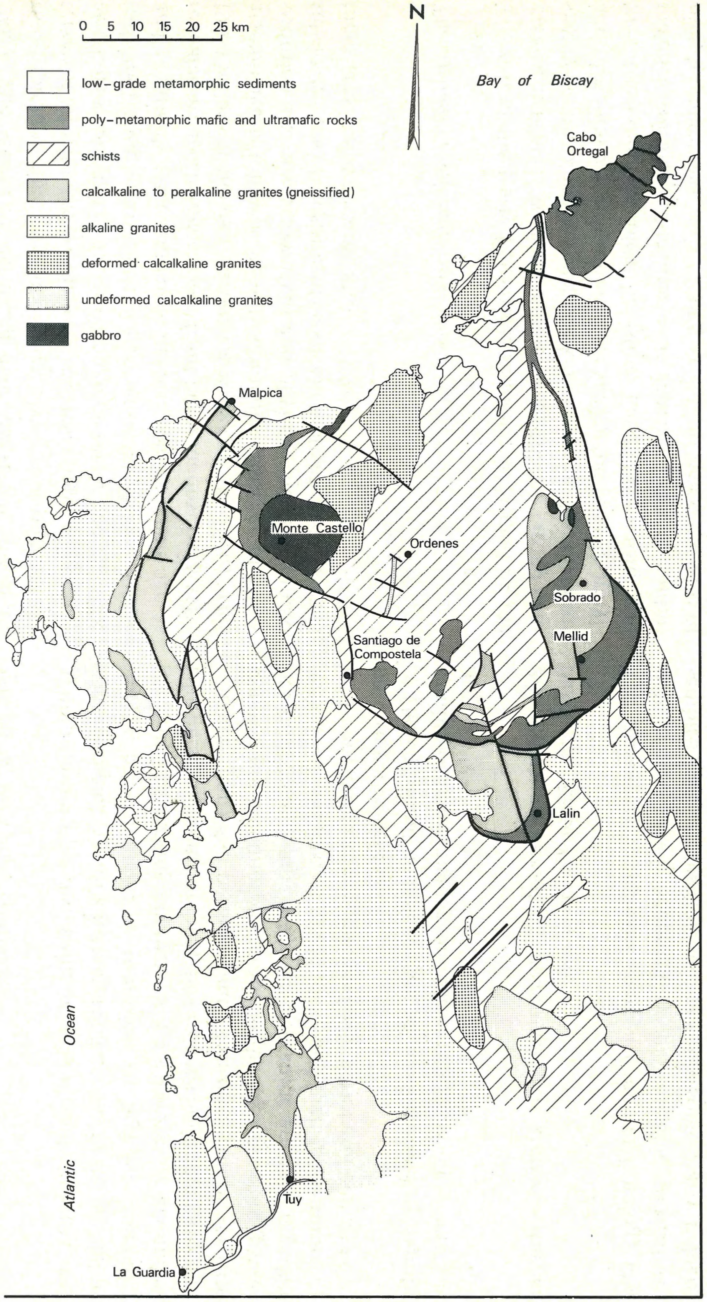

Fig. 1
Simplified map of the northern Hesperian Massif in Galicia (NW Spain). After P. W. C. van Calsteren (1977-a).

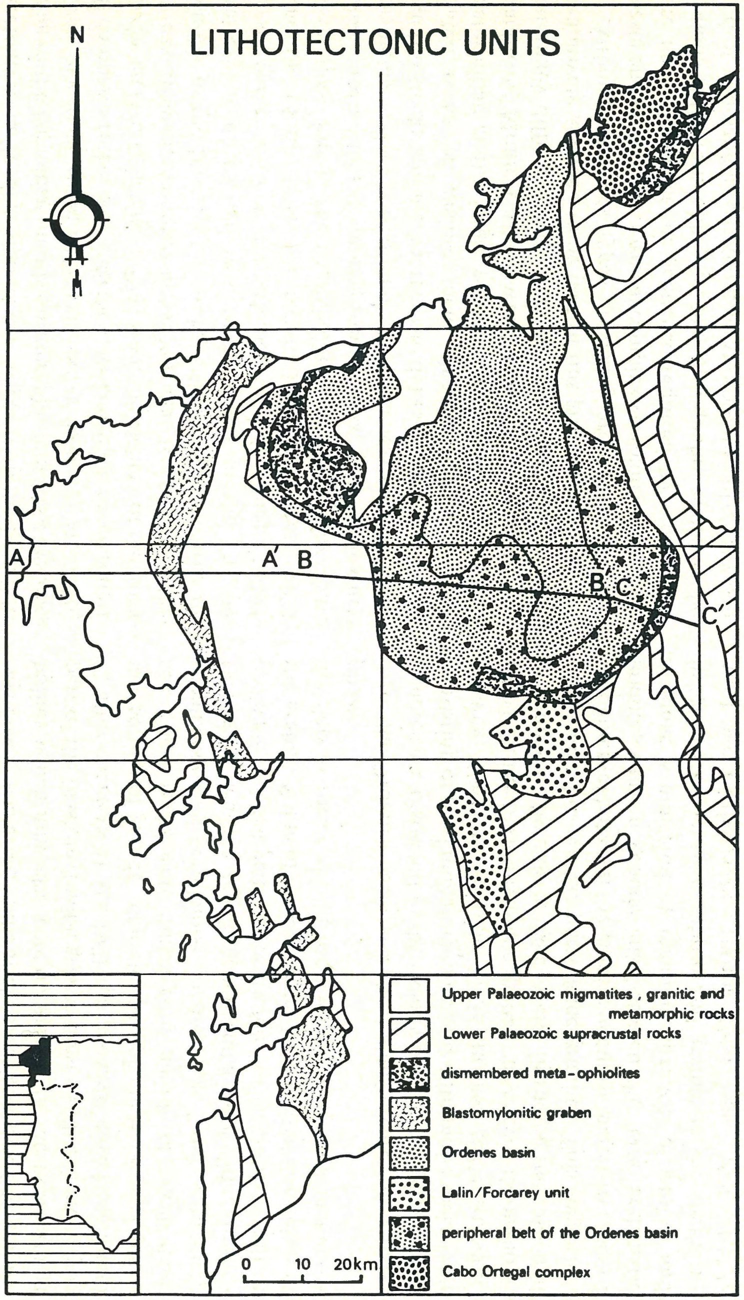

Fig. 2
Index map of lithotectonic units in the northern Hesperian Massif, showing the trace of the section.

1968). The sediments occurring here are rather similar to those found in the areas mentioned above, but they are interstratified with and overlain by arkoses, crinoidal limestones, coarse quartzites, (micro-)conglomerates, and rhyolitic tuffs indicating epicontinental deposition in a shallow sea, and eventually penecontemporaneous erosion. Their age as revealed by fossils may range from late Llandovery (MATTE, 1968) to late Wenlock (FERNANDEZ POMPA ET AL., 1976). This assemblage is followed by a monotonous sequence of interstratified arkoses, graywackes and phyllites indicating rapid subsidence and deposition of clastics in probably Late Silurian times (FERNANDEZ POMPA ET AL., 1976).

The dismembered meta-ophiolites

The top of the Early Palaeozoic sequence is formed by the greenschist-facies volcano-sedimentary Moeche Group consisting mainly of mafic volcanics, keratophyres, flasergabbros and serpentinites with subordinate variegated (quartz-)phyllites, cherts and crinoidal limestone lenses. The group also includes volcano-sedimentary and tectonic breccias containing fragments not only of all coeval rock types, but also of the infracrustal catazonal rocks exposed in the adjoining Cabo Ortegal complex. The Moeche Group may be described either as a tectonic melange or as an olistostrome (HSÜ, 1974; MARTINEZ GARCIA, 1975) suggesting deposition in a deep furrow localized between an exhumed basement complex and a continental platform, involving more or less coeval tectonization. Its depositional age ranges from the Late Silurian to the Devonian on lithostratigraphic and fossil evidence (VAN DER MEER MOHR, 1975; FERNANDEZ POMPA ET AL., 1976). It compares rather well with the Late Devonian flysch reported by RIBEIRO & RIBEIRO (1974) from the vicinity of the infracrustal Bragança complex in NE Portugal. Rock suites rather similar to the Moeche Group have been reported from the eastern, southern and western perimeter of the Ordenes basin peripheral belt near Mellid, Villa de Cruces, Silleda and the Monte Castelo (KONING, 1966; HUBREGTSE, 1973; WARNAARS, 1967). The amphibolites and metagabbros have characteristic fabrics ranging from laminar to flaser textures of highly variable orientation. More or less massive metagabbro stocks and metaporphyrite dykes cut across these foliated rocks or enclose them. Pending radiometric age determination the large, predominantly non-metamorphic, gabbro of Monte Castelo, which consists of a sequence of internally differentiated layers or sills (WARNAARS, 1967), is tentatively assumed to be part of this group of rocks.

Although the rock types prevailing around the Ordenes basin and in the Cabo Ortegal complex vary considerably and are never found in the sequence required by recent definitions of the term ophiolite, they may qualify as dismembered or non-sequence ophiolites (ANONYMOUS, 1972; MIYASHIRO, 1973) or as melanges (HSÜ, 1974) in a distinctly tectonized and metamorphic state.

The infracrustal rock complexes

Within this group a distinction may be made between mesozonal complexes with a metamorphic climax in the amphibolite facies, containing a profusion of high-level granitic gneisses and lacking appreciable positive gravity anomalies (the blastomylonitic graben, the Ordenes basin, the Lalin and Forcarey unit) and predominantly catazonal complexes with a maximum metamorphic grade in the high-pressure granulite facies, containing lower-level granitic gneisses together with an abundance of mafic rocks and high-temperature or root-zone peridotites (Ordenes basin peripheral belt and Cabo Ortegal complex).

The catazonal complexes are all accompanied by significantly positive Bouguer anomalies (up to 38 mgal amplitude).

The mesozonal complexes: blastomylonitic graben, Ordenes basin, and Lalin/Forcarey unit

The mesozonal complexes share a common lithology and petrogenesis. Their sedimentary and volcanic content resembles Late Proterozoic and possibly some Early Palaeozoic strata in eastern Galicia and northern Portugal. The rocks were mainly graywackes, (semi-)pelites, sandstones, cherts, calcareous or dolomitic marls and predominantly mafic lavas or tuffs. Regional metamorphism in the high- to intermediate-pressure facies series has first affected these rocks giving rise to biotite and garnet in the schists and paragneisses, while the mafic rocks were converted to amphibolites which may also contain garnet. In the northermost part of the blastomylonitic graben lenses with eclogitic (type C, after COLEMAN ET AL., 1971) parageneses have been found in a setting of garnet-, epidote- and phengite-bearing gneisses. These rocks were intruded by high-level calcalkaline, subalkaline and peralkaline granites. The latter, containing riebeckite, aegirine, lepidomelane and astrophyllite, are subordinate and distinctly concentrated in the southern half of the graben. Some of these granites have caused hornfelses to develop in rocks of non- or low-grade regional metamorphism.

In the Ordenes basin and the Lalin/Forcarey unit these granites are restricted to the vicinity of their peripheral belts consisting of predominantly mafic, c.q. ultramafic rocks (VAN ZUUREN, 1969; HUBREGTSE, 1973; HILGEN, 1971; MINNIGH, 1975). In the blastomylonitic graben they occur throughout, accompanied by a basic dyke swarm intruding the calc- and subalkaline but not the peralkaline granites. This suggests a time interval between the emplacement of these two types of granite, while a genetic link between the felsic and mafic magmas is indicated by minor occurrences of gabbro and hybrid rocks between gabbro and granite in the southernmost part of the graben (FLOOR, 1966; ARPS , 1970). Rb-Sr whole-rock isochrons of these strongly gneissified granites (PRIEM ET AL., 1970; VAN CALSTEREN ET AL., 1979-a) indicate a

Middle to Late Ordovician age for their first crystallization. The morphology of their zircon crystals supports the contention that they were primarily emplaced as high-level magmatic granites (ARPS, 1970).

During the third and fourth deformation phases these assemblages of rocks were first isoclinally folded or flattened on subhorizontal N-S trending axes, and metamorphosed (but never migmatized) in grades ranging from greenschist to cordierite-amphibolite facies. MINNIGH, (1975) and MATTE & CAPDEVILA (1978) were able to demonstrate the presence of an inverted sequence in the Forcarey unit, and of a large-scale recumbent fold facing West in the northern Ordenes basin. Refolding on subvertical N-S trending axial planes and local retrogradation followed. In this process the granitic rocks first developed a blastomylonitic texture and foliation, marked by biotite ± garnet or riebeckite ± aegirine, which was subsequently folded and recrystallized under low-grade amphibolite- or greenschist-facies conditions.

The blastomylonitic graben, between Malpica and Tuy, is a narrow belt of submeridional trend, bounded by steeply inward dipping faults, parts of which are occupied by elongate bodies of biotite granodiorite. After an inferred Early Palaeozoic phase of subsidence it was compressed during F_3, but it subsided again after the emplacement of the earlier Palaeozoic granites (ARPS, 1970).

The Ordenes, Lalin and Forcarey complexes are all more or less basin-shaped structures, of variable size, open-ended to the North, and overthrust or overfolded to the S, W and E onto Palaeozoic strata along more or less gently inward dipping (blasto-)mylonite zones and thrust faults. This movement must have occurred before the climax of the M_3 metamorphism since the latter's isograds pass undisturbed from the central Galician schist area into the Forcarey/Lalin unit (HILGEN, 1971; MINNIGH, 1975).

The catazonal complexes: Cabo Ortegal and Ordenes basin peripheral belt

This group of circular to oval-shaped complexes represents an even deeper crustal level than the preceeding one. Similarly, a common lithology and petrogenesis is shared by them. Mafic and ultramafic rocks constitute up to 75% of their surface areas. Ultramafic bodies generally have a core of spinel-lherzolite with spinel-free websterite, wehrlite, garnet- or spinel-pyroxenite and pargasite/phlogopite-bearing layers and veins. Their mineralogical and chemical constitutions reflect an upper mantle origin as garnet- or aluminous pyroxene-pyrolites producing small amounts of picritic or pyroxenitic liquids, and leaving a spinel-lherzolite as solid residue during their rise through the upper mantle into the lower continental crust (MAASKANT, 1970). Subsequently the ultramafic cores have suffered the same tectonic and metamorphic history as the eclogites, mafic and felsic granulites, amphibolites and garnet-kyanite-biotite gneisses of their immediate context.

The distribution of major and trace elements in the mafic Cabo Ortegal rocks led VAN CALSTEREN (1978) to distinguish between continental quartz-normative tholeiites – as represented by the mafic granulites and eclogites from the context – and olivine-normative tholeiites of oceanic island or mantle-plume type as represented by the Early Palaeozoic gabbros, pyroxenites and amphibolites derived from the lherzolite by partial melting.

VAN CALSTEREN (1977-a, b) developed a two-stage melting model for the Cabo Ortegal ultramafics on the basis of their chondrite-normalized La/Sm and K/Rb ratios:

(1) a spinel-lherzolite melt fraction from a deep mantle plume; and

(2) a pargasite-peridotite residual fraction yielding partial melts of pyroxenite, pargasite-phlogopite rock and gabbro.

VAN CALSTEREN ET AL. (1979) also studied the geochronology of the rocks and minerals in question. They found Rb-Sr whole-rock isochron ages of 477 ± 122 Ma for the lherzolites of Cabo Ortegal and of 347 ± 17 Ma for the mafic granulites of its context, whereas the eclogite plots did not allow a linear correlation on the Nicolaysen diagram. K-Ar mineral ages from the catazonal rocks show a peak in the frequency histogram at 400 Ma. This is taken to mean that the lherzolite whole rock systems closed first (in Cambro-Silurian times) followed by their constituent minerals and immediate country rocks, while the thermal event terminated with the closure of the hornblende granulite systems at the end of the Devonian.

Gravity surveys, carried out by VAN OVERMEEREN (1975) and by KEASBERRY ET AL. (1976, 1979), have demonstrated the existence of positive Bouguer anomalies with amplitudes from 10-38 mgal over Cabo Ortegal, Sobrado/Teijeiro, Mellid and the Santiago complex suggesting the presence of high-density bodies with generally steep contact surfaces reaching depths between 3 and 11 km, depending on the density contrast and shape model chosen. Surrounding or overlying the mafic-ultramafic complexes cata- to mesozonal associations of felsic granulites, ga-ky-bi-gneisses, and blastomylonites, as well as garnetiferous augen- and orthogneisses are generally present. The latter two rock types frequently contain pods of more or less hybridized garnet-bearing gabbro or diorite (globuliths after BERTHELSEN, 1970). These rocks are inferred to represent the deepseated equivalents (c.q. root-zones) of the para- and orthogneisses encountered in the blastomylonitic graben, Ordenes basin and Lalin/Forcarey unit.

Polyphase deformation was demonstrated for these complexes by VOGEL (1967), VAN ZUUREN (1969), WARNAARS (1967), MAASKANT (1970), ENGELS (1972) and HUBREGTSE (1973). N-S trending fold axes in paragneisses and eclogites represent the earliest deformation phase (F_0), followed by recumbent folds (F_2) on E-W and N-S axes occurring in all catazonal rocks, and by the development of peripheral blastomylonites (F_3) around the ultramafic and garnetiferous granitic gneiss bodies. Refolding on steep NNE trending axial planes (F_4) took place during the late Palaeozoic accompanied by retrogradation in the amphibolite facies.

Further retrogradation took place prior to F_5 when the catazonal complexes were upthrusted against their meso- and epizonal context, locally coming to rest upon low-grade Siluro-Devonian sea-floor associations such as the Moeche Group.

OUTLINE OF THE PREFERRED MANTLE-PLUME/ RIFT SYSTEM MODEL FOR THE EVOLUTION OF THE NORTHERN HESPERIAN MASSIF

Most of the supra- and infracrustal data, presently available for the northern Hesperian Massif, are consistent with a mantle-plume/rift-system model of its development between late Proterozoic and Permian times.

The mantle-plume model was developed by VAN CALSTEREN (1977-a, b, 1978, 1979) in coherence with geochronological, geochemical and geophysical data from the catazonal complexes at Cabo Ortegal and in the peripheral belt of the Ordenes basin. According to this model a first-order mantle-plume and its second-order diapiric offshoots in the lower crust have caused doming, rifting and thinning of the continental crust in the axial zone. The second-order diapirs can be held responsible for the aureoles of high-pressure granulite facies granofelses and their subsequent hydration and partial fusion to hornblende granulite facies blastomylonites in the immediate vicinity of the lherzolite diapirs. Contact anatexis of lower crustal materials, probably aided by the segregation of large bodies of gabbroic magma, can explain the close association of the garnetiferous augen- and ortho-gneisses with the ultramafic-mafic central complexes, as well as the hybrid gabbroic globuliths in the granitic gneisses.

A rift-system, caused by the mantle-plume, is exemplified by the inferred presence of an early Palaeozoic graben structure in western Galicia (DEN TEX, 1961, 1966, 1967-a, b; DEN TEX & FLOOR, 1967; ARPS, 1970) containing, e.g., high-level peralkaline granites and bimodal (sub-)volcanics which were folded, flattened and remetamorphosed in Palaeozoic times, closely followed by renewed subsidence.

Evidence of taphrogenic movements and bimodal magmatic activity occurring throughout the northern Hesperian Massif can also be quoted in support of crustal rifting during late Proterozoic and early Palaeozoic times. The presence of a pre-late Proterozoic continental crust is confirmed by the existence of the Ollo de Sapo Belt and by the early Proterozoic upper intercept ages of discordant zircons from ortho-, augen- and paragneisses (KUIJPER, 1979).

The occurrence of dismembered meta-ophiolites, volcanics and melanges of Siluro-Devonian age, containing debris of the adjoining catazonal complexes is interpreted as evidence of incipient but arrested sea-floor spreading in the vicinity of the second-order lherzolite diapirs (Cabo Ortegal, Sobrado/ Teijeiro, Mellid). In this part of the model mass movement of hot rock and magma is used to explain both the mechanical and thermal events that are recorded in the Early Palaeozoic rocks, minerals and structures concerned (see Table 1).

In the present paper reference to Variscan or other orogeneses is deliberately avoided. Although the spatial and temporal relations between late Proterozoic, early and late Palaeozoic magmatic, metamorphic and tectonic events are not quite resolved, it is believed that they constitute a coherent dynamo-thermal sequence that offers no grounds for a div-

Table I
Correlation table of geological events in the northern Hesperian Massif.

	Infracrustal rock complexes		Late Palaeozoic migmatites, granitic and metamorphic rocks	Early Palaeozoic rock sequences	
	catazonal	mesozonal		supracrustal rocks	dismembered meta- ophiolites
M_4 ca. 290	F_5: chevron folding and thrusting, greenschist facies	normal faulting granite intrusions	granite intrusions		
M_3 ca. 310	amfibolite facies, F_4: N-S isoclinal folding, vertical axial plane	development of foliation in granites, wrench faulting, granite emplacement	L-IP metamorphism, deformation, granite emplacement, migmatization	anchi- to low- grade metamorphism	dolerite dykes, Devonian to Carboniferous carbonates and greywackes, melange formation
M_2 350	hornblende granulite facies, F_2: N-S, F_3: E-W horizontal axial plane, blastomylonitization, gneissification intrusion of mafic plugs	blastomylonitization, gneissification, intrusion peralkaline granites, intrusion mafic dikes		Silurian to Devonian sedimentation of carbonates pelites and quartzites with bimodal volcanics	gabbro stocks, serpentinites, Silurian to Devonian sedimentation of carbonates, pelites and quartzites with bimodal volcanics
400					
M_1 500	granite emplacement (protolith of ortho- and augengneisses) granulite facies F_1: N-S, horizontal axial plane mantle-plume activity starts	gabbros, hybridization, granite emplacement (protolith of ortho- and augengneisses)	Cambrian to Ordovician sedimentation of arenaceous to pelitic rocks, with bimodal volcanics	Cambrian to Ordovician sedimentation of arenaceous to pelitic rocks with bimodal volcanics	
	prograde eclogitization (B type), F_0	eclogitization (C type)			
	burial	burial			
>1000 <1500	emplacement of mafic rocks, sedimentation of (semi) pelites, greywackes, sandstones, carbonates, cherts etc	emplacement mafic rocks, sedimentation of (semi) pelites greywackes, sandstones, carbonates cherts etc			
ca. 2500	erosion, granitic basement ?				

ision into Variscan and pre-Variscan orogenic cycles. In the absence of a significant time gap between the hornblende granulites at Cabo Ortegal (347 ± 17 Ma) and the earliest Late Palaeozoic granites (311 ± 21 Ma) and with evidence for subduction of oceanic lithosphere virtually lacking, plate tectonic collision models for the northern Hesperian Massif (whether Variscan or Caledonian), as proposed by ANTHONIOZ (1969), FERRAGNE (1972), RIES & SHACKLETON (1971), MARTINEZ GARCIA (1973), ALDAYA ET AL. (1973), BARD ET AL. (1973), RIBEIRO (1974), RIDING (1974), BADHAM & HALLS (1975) and ANTHONIOZ & FERRAGNE (1978) appear to miss the main point. For a critical review of these models the reader is referred to DEN TEX (in press).

ACKNOWLEDGEMENTS

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REFERENCES

Aldaya, F., A. Arribas, F. Gonzalez-Lodeiro, M. Iglesias, J. R. Martinez-Catalan & E. Martinez Garcia 1973 Presencia de una nueva fase de deformacion probablemente pre-hercinica en el noroeste y centro de la peninsula iberica (Galicia central, Zamora y Salamanca) – Stud. Geol. Salamanca 6: 29-48.

Aldaya, F., P. Carls, E. Martinez Garcia & J.-L. Quiroga 1976 Nouvelles précisions sur la série de San Vitero (Zamora, Nord-Ouest de l'Espagne) – C. R. Acad. Sci. Paris 283 D: 881-883.

Anonymous 1972 Penrose field conference on ophiolites – Geotimes 17 (12): 24-25.

Anthonioz, P. M. 1969 Étude pétrographique et structurale des régions de Morais et Bragança (NE Portugal) – Thèse Univ. Poitiers: 311 pp.

Anthonioz, P. M. & A. Ferragne 1978 Le Précambrien polymétamorphique allochthone du Nord-Ouest de la Péninsule Ibérique, témoin d'une nappe de charriage calédonienne? In: M. Julivert et al., (eds.): Geología de la Parte Norte del Macizo Iberico – La Coruña: 23-42.

Arps, C. E. S. 1970 Petrology of a part of the Western Galician basement between the Rio Gallas and the Ria de Arosa (NW Spain) with emphasis on zircon investigations – Leidse Geol. Meded. 46: 57-155.

Arps, C. E. S., P. W. C. van Calsteren, J. D. Hilgen, R. P. Kuijper & E. den Tex 1977 Mafic and related complexes in Galicia: an excursion guide – Leidse Geol. Meded. 51: 63-94.

Badham, J. P. N. & C. Halls 1975 Microplate tectonics, oblique collisions, and evolution of the Hercynian orogenic systems – Geology 3: 373-376.

Bard, J.-P., R. Capdevila, Ph. Matte & A. Ribeiro 1972 Le Précambrien de la méséta ibérique – Notes Mém. Serv. Géol. Maroc. 236: 315-335.

Berthelsen, A. 1970 Globulith – a new type of intrusive structure exemplified by metabasic bodies in the Moss area, SE Norway – Norges Geol. Undersøk. 266: 70-85.

Buiskool Toxopeus, J. M. A., P. E. M. Haalebos & F. A. van Overmeeren 1978 An outline of the petrology and structural geology of the Hercynian complex, South of Vigo (Pontevedra, Spain). In: M. Julivert et al. (eds.): Geología de la Parte Norte del Macizo Iberico – La Coruña: 93-110.

Capdevila, R. 1965 Sur la géologie du Précambrien et du Paléozoique dans la région de Lugo et la question des plissements assyntiques et sardes en Espagne – Notas Comm. Inst. Geol. Min. España 80: 157-174.

Capdevila, R. & P. Floor 1970 Les différents types de granites hercyniens et leur distribution dans le nord ouest de l'Espagne – Bol. Geol. Min. 81: 215-225.

Capdevila, R., G. Corretge & P. Floor 1973 Les granitoides varisques de la Meseta ibérique – Bull. Soc. géol. France 15: 209-228.

Den Tex, E. 1961. Some preliminary results of petrological work in Galicia (NW Spain) – Leidse Geol. Meded. 26: 75-91.

——1966 Aperçu pétrologique et structural de la Galice cristalline – Leidse Géol. Meded. 36: 211-222.

——1977 Le socle polycycline et son rôle dans l'évolution de la Chaîne Varisque en Galice occidentale (Espagne du NW) – Coll. Int. C.N.R.S. 243: La Chaîne Varisque d'Europe Moyenne et Occidentale (Rennes, 26 sept.-Oct. 1974) Abstr. and Proc. 67-78.

——(in press) Basement evolution in the northern Hesperian Massif. A preliminary survey of results obtained by the Leiden research group – Leidse Geol. Meded.

Den Tex, E. & P. Floor 1967 A blastomylonitic and polymetamorphic 'Graben' in Western Galicia (NW Spain) – Etages Tectoniques. A la Baconnière (Neuchatel): 169-178.

De Roever, W. P. & H. J. Nijhuis 1963 Plurifacial Alpine metamorphism in the eastern Betic Cordilleras (Southeast Spain) with special reference to glaucophane – Geol. Rundschau 53: 324-336.

Engels, J. P. 1972. The catazonal polymetamorphic rocks at Cabo Ortegal (NW Spain). A structural and petrofabric study – Leidse Geol. Meded. 48: 83-133.

Fernandez Pompa, F., V. Monteserin & T. Piera Rodriguez 1973 Mapa geológico y memoria explicativa de la Hoja 1 (06-03) a E. 1:50.000 (Ortigueira) – Publ. I.G.M.E. (Madrid).

Ferragne, A. 1972 Le Précambrien et le Paléozoique de la Province de l'Orense (Nord-Ouest de l'Espagne). Stratigraphie-Tectonique-Métamorphisme – Thèse Univ. Bordeaux I: 249 pp.

Floor, P. 1966. Petrology of an aegirine-riebeckite-gneiss bearing part of the Hesperian Massif: the Galineiro and surrounding areas, Vigo, Spain – Leidse Geol. Meded. 36: 1-204.

——1970 Session de travail consacrée à la subdivision des roches granitiques hercyniennes dans le Nord-Ouest Péninsulaire – Bol. Geol. Min. 81: 245-248.

Floor, P., H. J. Kisch & Oen Ing Soen 1970 Essai de corrélation de quelques granites hercyniens de la Galice et du Nord de Portugal – Bol. Geol. Min. 81: 242-244.

Hensen, B. J. 1967 Mineralogy and petrography of some tin, lithium and beryllium bearing albite-pegmatites near Doade, Galicia, Spain – Leidse Geol. Meded. 39: 249-259.

Hilgen, J. D. 1970 Algunas observaciones sobre el granito profiroide de Fontao y su mineralizacion metalifera – Bol. Geol. Min. 31: 199-210.

——1971 The Lalin Unit: a new structural element in the Hercynian orogen of Galicia (NW Spain) – Proc. Kon. Ned. Akad. Wet. B 74: 1-10.

Hsü, K. 1974 Melanges and their distinction from olistostromes. In: Modern and ancient geosynclinal sedimentation – Soc. Econ. Pal. Min. Spec. Publ. 19: 321-333.

Hubregtse, J. J. M. W. 1973-a Petrology of the Mellid area, a Precambrian polymetamorphic rock complex, Galicia, N.W. Spain

– Leidse Geol. Meded. 49: 9-31.

——1973-b Distribution of elements in some basic granulite facies rocks – Verh. Kon. Ned. Akad. Wet. Amsterdam 27: 68 pp.

Keasberry, E. J. 1979 An interpretation model of semi-circular Bouguer anomalies found over the peripheral belt of the Ordenes Complex (NW Spain) – Geol. Mijnbouw 58: 65-70.

Keasberry, E. J., P. W. C. van Calsteren & R. P. Kuijper 1976 Early Palaeozoic mantle diapirism in Galicia – Tectonophys. 31: T61-75.

Koning, H. 1966. Les types de roches basiques et ultrabasiques qu'on rencontre dans la partie occidentale de la Galice (Espagne) – Leidse Geol. Meded. 36: 235-242.

Kuijper, R. P. (1979) U-Pb systematics and the petrogenetic evolution of infracrustal rocks in the Paleozoic basement of Western Galicia (N.W. Spain) – Verhand. ZWP Lab. Isotopengeol. Amsterdam 5: 101 pp.

Maaskant, P. 1970 Chemical petrology of polymetamorphic ultramafic rocks from Galicia, N.W. Spain – Leidse Geol. Meded. 45: 237-325.

Martinez Garcia, E. 1973 Deformación y metamorfismo en la zona de Sanabria – Stud. Geol. Salamanca 5: 7-106.

Martinez Garcia, E., F. Fernandez Pompa, M. Arce, F. Fernandez Martinez, J. Fernandez Tomas & V. Monteserin 1975 Nuevos datos para la interpretación del complejo basico de Cabo Ortegal (Galicia, Noroeste de España) – Tecniterrae 7: 8-12.

Matte, Ph. 1968 La structure de la virgation hercynienne de Galice (Espagne) – Géol. Alpine 14: 157-280.

Matte, Ph. & R. Capdevila 1978 Tectonique en grands plis couchés et plissements superposés d'âge hercynien dans la série de Ordenes-Betanzos (Galice occidentale). In: M. Julivert et al. (eds.); Geologia de la parte Norte del Macizo Iberico – La Coruña: 193-202.

Minnigh, L. D. 1975 Tectonic and petrographic aspects of an area SW of the Lalin unit (Prov. Orense and Pontevedra, N.W. Spain) – Leidse Geol. Meded. 49: 499-504.

Miyashiro, A. 1973 Metamorphism and metamorphic belts – G. Allen & Unwin Ltd. (London): 95 pp.

Parga Pondal, I. 1966 Datos geológico-petrográficos de la Provincia de la Coruña. In: Estudio agrobiológico de la Provincia de la Coruña. Inst. Invest. Geol. Edafol. Agrobiol. de Galicia (C.S.I.C.), (Vigo): 46 pp.

Priem, H. N. A., N. A. I. M. Boelrijk, R. H. Verschure, E. H. Hebeda & E. A. Th. Verdurmen 1970 Dating events of acid plutonism through the Paleozoic of the Western Iberian Peninsula – Eclog. Geol. Helv. 63: 255-274.

Read, H. H. 1949 A contemplation of time in plutonism – Q. J. Geol. Soc. London 105: 101-156.

Ribeiro, A. 1974 Contribution à l'étude tectonique de Tras-os Montes oriental – Serv. Geol. Portugal Mem. 24: 1-168.

Ribeiro, L. R. & A. Ribeiro 1974 Signification paléogéographique dans un flysch d'âge Dévonien supérieur du Tras-os-Montes oriental (Nort-Est du Portugal) – C. R. Acad. Sci. Paris 278: 3161-3163.

Riding, R. 1974 Model of the Hercynian fold belt – Earth Planet. Sci. Letters 24: 125-135.

Ries, A. C. & R. M. Shackleton 1971 Catazonal complexes of North-West Spain and North Portugal, remnants of a Hercynian thrust plate – Nature Phys. Sci. 234: 65-68.

Van Calsteren, P. W. C. 1977 A mantle-plume model interpretation for the Paleozoic geology of Galicia with emphasis on the Cabo Ortegal area (NW Spain) – Proc. Kon. Ned. Akad. Wet. B 80: 156-168.

——1978-a Geochronological, geochemical and geophysical investigations in the high-grade mafic-ultramafic complex at Cabo Ortegal and other pre-existing elements in the Hercynian basement of Galicia (NW Spain) – Leidse Geol. Meded. 51: 57-61.

——1978-b Geochemistry of the polymetamorphic mafic-ultramafic complex at Cabo Ortegal (NW Spain) – Lithos 11: 61-72.

Van Calsteren, P. W. C., N. A. I. M. Boelrijk, E. H. Hebeda, H. N. A. Priem, E. den Tex, E. A. Th. Verdurmen & R. H. Verschure 1979 Isotopic dating of older elements (including the Cabo Ortegal mafic-ultramafic complex) in the Hercynian orogen of NW Spain: Manifestations of a presumed early Paleozoic mantle plume – Chem. Geol. 24: 35-56.

Van Calsteren, P. W. C. & E. den Tex 1978 An early Paleozoic continental rift system in Galicia (NW Spain). In: I. B. Ramberg & E.-R. Neumann (eds.): Tectonics and geophysics of continental rifts – D. Reidel Publ. Co. (Dordrecht): 125-132.

Van der Meer Mohr, C. G. 1975 The Paleozoic strata near Moeche in Galicia, NW Spain – Leidse Geol. Meded. 49: 487-497.

Van Meerbeke, G. L. E., J. D. Hilgen & P. Floor 1973 Preliminary results of the investigation of the central Galician schist area (Prov. of Orense and Pontevedra, NW Spain) – Leidse Geol. Meded. 49: 33-37.

Van Overmeeren, R. A. 1975 A gravity investigation of the catazonal rock complex at Cabo Ortegal (NW Spain) – Tectonophys. 26: 293-307.

Van Zuuren, A. 1969 Structural petrology of an area near Santiago de Compostela (NW Spain) – Leidse Geol. Meded. 45: 1-71.

Vogel, D. E. 1967 Petrology of an eclogite- and pyrigarnite-bearing polymetamorphic rock complex at Cabo Ortegal, NW Spain – Leidse Geol. Meded. 40: 121-213.

Warnaars, F. W. 1967 Petrography of a peridotite-, amphibolite- and gabbro-bearing polyorogenic terrain NW of Santiago de Compostela (Spain) – Ph. D. thesis Univ. Leiden: 208 pp.

Ypma, P. J. M. 1966 Sumario de la mineralización metalifera y su genesis en Galicia occidental (Espana) – Leidse Geol. Meded. 36: 279-291.