FIELD TRIP GUIDE
A-3
SIXTH INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

GALICIA REGION: LANFORMS AND MORPHOLOGICAL EVOLUTION OF GRANITIC AREAS

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Geomorphological outlines of the NW Iberian Peninsula.

The morphology of the NW of the Iberian Peninsula is defined at least from the beginning of the Caenozoic with the opening of the Atlantic Ocean. The coast traits of the NW of Iberia are, as other well-known cases as the Guinea Gulf in Africa and its counterpart of South America, a clear example of the relation between plate tectonics and the shape of the continents. The right angle between the Atlantic and Cantabrian coast is perhaps the best preserved traces of the break of the triple junction from which the Iberian Peninsula spread out (Fig. 1) from the rest of Pangea at the end of the Mesozoic (Williams, 1975; Frisch, 1980). Inside the Iberian Plate, part of the old continent is even recognized in the remnants of the older surface (Main Surface +700 m a.s.l.) still preserved in great fragments along the whole perimeter of the Atlantic Iberian coast then continued towards the South along the whole Atlantic border of the NW Iberian Peninsula, though affected by the NNE fault, which separates the Mesozoic-Caenozoic of the Hesperian Massif. The Superficie Fundamental or Main Surface (M.S.) was elaborated at the Paleogene prearcosic stage (Pedraza, 1978) of Late Miocene age. Their present fragmentation was essentially done by the action of fluvial incision exacerbated by the appearance of the new base levels especially the more active Atlantic ones.

From a geodynamic viewpoint, two domains are distinguished in the zone: the North, or Cantabrian border, and the West, or Atlantic border, each with a distinct evolution (Fig. 2). From the Caenozoic the two zones suffer the fracture effect of Pangea in a very different way; while the north margin behaves, at least until the Eocene, as a collision border (Gallastegui, 2000; López-Fernández, C. et al., 2004; Fügenschuh et al., 2003), the Atlantic one behaved as a distensive/extensive (passive) border from the beginning of the fragmentation of Pangea (Boillot & Malod, 1988). This zone has all the elements of a classic subduction border: continental trench, with its small accretion sedimentary prism, a surface level located at the border of the coast, with variable altitudes above the sea level and generally called Cantabrian abrasion platform (misinterpreted as of marine origin (Hernández Pacheco, 1949; Nonn 1960; Mensching 1961)), the orogenic chain (Olivet et al., 1983; Vidal Romání et al., 1998; Gallastegui 2000; López-Fernández, C. et al., 2004) and behind the altiplano formed by highly degraded fragments of the Main Surface of Galicia (Yepes, 2002). Some authors (Twidale and Vidal Romani, 2005) justified the incision of the fluvial system by the post collision isostatic rebound, aspect which seems to be confirmed in the continental zone (Santanach, 1994; Santanach et al., 1988; Vidal Romani et al., 1998) by the inverse character of the fault systems which affect the whole Cantabrian border (Santanach, 1994), included the submerged zone (Gallastegui, 2000). The physiography of the west border is totally different and behaved as a passive margin with influence of the distension up to now. Therein the lithosphere has been cooled progressively (thermoisostasy) while separating from the centre of the mid Atlantic ocean ridge (Watts, 2001), as far as Iberia separated from North America and the Atlantic fluvial systems were being developed, penetrating inside Iberia and eroding its inner zones. The west continental Platform...
sinks as result of the accumulation of sediments in the now submerged platform and which would have been very important during the whole Tertiary (Vanney et al., 1979). The evolution of a passive plate border (Watts, 2001) implies the appearance of specific morphotectonic features: graben associated to the listric fault systems and isostatic rebound of the emerged border encompassed with the incision of the whole fluvial network, especially the Atlantic one. In the rest of the World there are similar cases as the described for the west coast of Iberia: Serra do Mar in Brazil, Drakensberg Mountains in South Africa, Great Escarpment in Australia, Grand Falaise in Madagascar (Summerfield, 1991). This positive eustatic movement acting on the Atlantic fluvial network has also been causing the formation of the western Galician Rías. Even though the age of the rías as primary marine forms is not known exactly, there are some hints (Rey, 1990) that enable to advance an approximate age (Neogene) for its invasion by the sea. According to Rey (1990), in the Upper Pliocene, the sea stops a dozen of kilometres from the present coastline to continue, after marine oscillations corresponding to the Pleistocene, penetrating enabling to give a more concrete age for the formation of Rías.

Figure 1. Separation of the Iberian Peninsula from the break of the triple junction.
Inside Iberia the formation of present fluvial valleys, characterized by very deep incisions, produced the exposure of the granitic bodies, intruded during the Hercynian Orogeny in the metasedimentary host-rock. The numerous granitic bodies that may be distinguished in the present relief of the Iberian NW, though with the same age, so Hercynian Orogeny, are exposed at different heights (between 1800 m and 0 m a.s.l.) to the action of the weathering agents at quite distinct external geodynamic processes: aeolian, marine, periglacial and glacial. Different authors who studied the development of this incision process give different reasons to justify it; almost always eustatic oscillations combined with differential movements of the continental border(s): tilting (Torre, 1958), rifting processes (Pannekoek, 1966 a,b); vaults (Fig. 3) (Martín Serrano, 1991), or simply by incision of the fluvial network (Von Richthofen, 1901; Pagés, 1996, 2000). Among the followers of the incision theory, some authors (Lautensach, 1941, 1945; Torre, 1958; Nonn, 1966) establish the role of the glacial/interglacial oscillations (Fig. 4) characteristic of the Pleistocene as the determinant cause of the vigorous excavation of the fluvial valleys of the Iberian Atlantic coast. The morphologic differences for the same coast in its sections: Cantabrian (short and little deep rías), Atlantic (long rías and deeply going into the continent) go together with the paradigmatic case of the Portuguese coast, continuation of the Galician Atlantic one. The postglacial flood of the Portuguese coast does not have a morphology similar to the described for the Galician coast. This difference is explained (Cabral, 1995; Ribeiro, 2002) by the tectonics of the Portuguese Atlantic coast that suffers a continuous uprise (Cabral, 1995). This first approximation to the understanding of the morphogenesis of the coastal border of the Iberian NW establishes the existence of different formation ages for these reliefs that have been invaded by

Figure 2. General geodynamic outline of the Cantabrian and Atlantic borders of the Iberian Peninsula.
the sea and are called as rías. In the case of the western rías (Laxe, Camariñas, Muros, Arousa, Pontevedra, Vigo) several observations establish their antiquity: on the one hand, the dimensions they acquired, and on the other, the antecedent character of the Atlantic fluvial network (Vidal Romani, 1996). As to the rías associated to the northern coast of Galicia (Ribadeo, Foz, Viveiro, Barqueiro, Ortigueira), they would be more recent; their formation would have begun in the Neogene and presumably during the Pyrenean Phase, in which the uprise of the Cantabrian border of Galicia is due to the plate convergence of Iberia and Eurasian plates (Gallastegui, 2000). With respect to the rías assembled around the Artabro Gulf (Ferrol, Ares, Betanzos and Coruña), their study (Nieto and Vidal Romani, 1989; Grajal, 1990) has been generally limited to the characterization of the remnants of surfaces and deposits. These rías, called by Torre (1958) as the transition rías (Fig. 5), seem to have an intermediate age between the Cantabrian rías and the rest of the Atlantic rías because the relative base level of the network that drains this area was some 60 m above its present position during the Pliocene (Escuer and Vidal Romani, 1987) allowing us to assign a Plio-Quaternary age to the fluvial incision, and therefore, to the installation of the ría type forms in the Artabro Gulf.

Figure 3. General outline of the formation of the rías by rifting processes.
Figure 4. Atlantic fluvial network with its incision processes due to the glacial/interglacial oscillations.
Stop 1: Costa da Morte. Playa de Trece

The morphologic features of this stop are developed on a unique lithology: granite of biotite that intrudes discordant into a gneissic anatexite granite forming therein a peculiar ring structure of kilometric dimensions. Though it is a coast of great energy, marine erosion forms of opposite meaning coincide in it as the rocky cliffs with vertical developments of more than a hundred of metres and shingle beaches, and alternate with sand beaches. Another characteristic of the coast is the so-called rocky abrasion platforms (Fig. 6) with anomalous dimensions for the type of rock on which they were abraded, and that the last interpretations (Twidale, Bourne and Vidal Romání, 2005) associate to chemical etching surfaces (Fig. 7) of continental origin, therefore, corresponding the shingle beaches (coidos) to accumulations of residual boulders better than to real beaches of marine accumulation. However, the high energy of the coast allows the development of real beach cusps with washover fans in the shingle beaches. Sand beaches also present high energy forms as blow out (Fig. 8), parabolic dunes and climbing dunes which corresponds, on the one hand, to high velocities of the wind typical of winter periods on the coast and also to the Venturi’s effect favoured by the coast topography with sudden changes of the coast line relief. As to the granitic morphology (Vidal Romani and Twidale, 1988; Twidale and Vidal Romání, 2005) the primary endogenous forms are very abundant and represented by different types of inselbergs (domes, rocky crests, castle kopje and tor), and at smaller dimensional scale: polygonal cracking, tafone and gnammas as well as primary exogenous forms such as rills (Fig. 9), which are here associated to dissolution processes developed under the thick
aeolian sand mantles with important calcareous component. The zone was severely affected by the spill of the tanker Prestige in November 2002 (Fig. 10) though fortunately it is now totally recovered at least as to the rocky landscape.

Figure 6. Etching surfaces misunderstood as marine abrasion platforms developed on granites.

Figure 7. Exposure of the weathering front at the high part of the “abrasion platform” of the previous figure.
Figure 8. Blow out at the Playa de Trece.

Figure 9. Rills developed by dissolution in granite under the aeolian mantle.
Stop 2: Monte Pindo. Xallas Fall (Lézaro embayment)

It is an outcrop with a dominant lithology: a biotitic granite with granodiorite trend which intrudes discordant with the structures of the Hercynian age host rock: the granites of the lineament Laxe-Muros-Barbanza and the migmatitic granitoids. There are two facies in the O Pindo granite (see map): biotite and muscovite-biotite, of medium to coarse grain (average grain of 4-6 mm). The texture is almost always inequigranular. This texture results from the difference between the mean size of the biotites and the felsic minerals, on the one hand, and the size variability of the latter, on the other.

The biotite content in both facies is relatively small (lower than 7%), and it is convenient to underline that the biotite facies is absolutely not a dark granite but pale instead. The granite is usually homogeneous at exposure scale or even at a greater scale. Not very important heterogeneities can be found regarding the muscovite distribution, the size and density of the feldspar megacrystals and the grain size of the rock.

In general, it can be said that the biotite facies is more homogeneous and more equigranular and it shows pinky or lilac colours. The facies of two muscovite-biotite micas is less homogeneous because of irregular distribution of muscovite and the presence of relatively feldspar rich coarse grain parts; its texture tends to be more porphyritic. Its alteration colours are usually whitish.
Each of these facies shows a different morphology. The biotitic one gives the dominant reliefs, which constitutes (Nonn, 1966) the complex inselberg of O Pindo cut by the Xallas River ending in the Lézaro embayment in a spectacular fall of 40 m (Fig. 11) direct to the sea. At this stop a great variety of granitic morphologies may be seen (Vidal Romaní and Twidale, 1998; Twidale and Vidal Romaní 2005) from the primary endogenous ones: domes very well developed with sheet structure, tor, castle kopje, tafone with a generalized development of honeycomb and gnammas in all their varieties. Also, there may be seen a good development of primary exogenous forms especially giant pot holes associated to the bed of the Xallas River in particular the one which constitutes the falling point of the fall. The incision of the Xallas River at the Monte Pindo constitutes one of the most highlighted references of the incision of the Atlantic fluvial network consequent with the break of Pangea being the top of the Pindo of 700 m height a residual of the Main Surface of Galicia. The dating using cosmogenic isotopes (Fernández Mosquera, 2002) (21Ne and 10Be) has allowed to infer the erosion rates of this long degradation process evaluating that the upper surface of the massif has been reduced some 300 m from the beginning of the opening of the Atlantic Ocean, and assigning a dominant role to the Pleistocene periglacial degradation which is especially seen in the close massif of A Ruña (Fig. 12), which appears surrounded by big scree mantles of granitic blocks giving evidence of the intensity of the periglacial phenomena in this zone during the Pleistocene. Five samples (Fig. 13) were analysed by cosmogenic elements (21Ne and 10Be), in order to define the history of the incision of Xallas River from the Pangea stage to the present times.
Figure 12. View of the south hillside of A Ruña covered with scree mantles of periglacial origin.

Figure 13. Localisation of the erosion surfaces dated by cosmogenic isotopes for the incision reconstruction of the Xallas River.
Stop 2a: PDO-1
Coordinates: 42°53’ 20N 9° 6’ 409W
Altitude: 637 m
$^{21}$Ne production rate: 30.0 at/g (Si) year
Lithology: quartz
Surface type: etched surface
Geomorphologic position: top of a residual, maximum local height
Geomorphologic age: Late Mesozoic (supposed)

The sample was taken from the summit (Fig. 14) of the O Pindo granite dome. It is a residual relief that was identified as rests of a very wide surface of 700 m, embracing the western part of Galicia. According to Pagés (1996), its age would be the end of the Mesozoic, although it does not provide either absolute chronological data or of any other kind. It is assimilated to the Fundamental Surface of Galicia (Nonn, 1966; Birot & Sole, 1954).

![Figure 14. Location of PDO1 and PDO3 at the inselberg of O Pindo.](image)

Stop 2b: PDO-2
Coordinates: 42°55’ 00N 9° 7’ 30W
Altitude: 147 m
$^{21}$Ne production rate: 19.3 at/g (Si) year
Lithology: granite (s.l.)
Surface type: fluvial erosion
Geomorphologic position: planation surface abandoned by the Xallas River
Geomorphologic age: Late Pliocene (supposed)

The sample was taken from the intermediate shoulder (147 m) (Fig. 15) of the course of the Xallas River at the back of the Lézaro embayment. Due to its location with respect to the present river course, it is considered a fluvial erosion surface though lately modified by the rock degradation (basins and tafone).
Stop 2c: PDO-3  
Coordinates: 42°55’ 15N  
9° 6’ 50W  
Altitude: 396 m  
$^{21}$Ne production rate: 24.3 at/g (Si) year  
Lithology: granite  
Surface type: fluvial erosion  
Geomorphologic: planation surface abandoned by the Xallas River  
Geomorphologic age: Miocene (supposed)  

The sample was taken from the upper shoulder (393 m) (Fig. 14) of the Xallas river course located above the Pindo Tank and at the same height as Penafiel (see photography 3.5). Due to its position with respect to the Xallas course it is considered a fluvial erosion surface though lately modified by the rock degradation (basins and tafoni).

Stop 2d: PDO-4  
Coordinates: 42°54’ 40N  
9° 7’ 40W  
Altitude: 73 m  
$^{21}$Ne production rate: 18.1 at/g (Si) year  
Lithology: granite (PDO-4) and quartz (PDO-4F)  
Surface type: fluvial erosion  
Geomorphologic position: planation surface abandoned by the Xallas  
Geomorphologic age: Lower Quaternary (supposed)  

The sample was taken from the lower shoulder (73 m) (Fig. 15) of the Xallas river course located on the embayment mouth of the Lézaro. It corresponds to a very distinctive episode (due to its good development) of the relief development. It is a fluvial erosion surface that shows rock degradation features (basins and tafoni).
Stop 2e: PDO-5
Coordinates: 42º52’04’’N
9º 7’ 10’’W
Altitude: 224 m
$^{21}$Ne production rate: 20.8 at/g (Si) year
Lithology: granite
Surface type: chemical etching
Geomorphologic position: surface
Geomorphologic age: Plio-Quaternary (supposed)

The sample was taken from the Lugar Onde se Adora and corresponding to a residual relief (224 m) over the surface of 200 m. It is considered an etched surface with later rock degradation (basins and tafoni). It shows a discontinuous soil cover (but not at the sample location).

Stop 3: Muros Ría. Monte Louro

Lithologically, this ría presents a great variety with predominance of the granitic facies: granite of two-micas, young granodiorite, which are the more extended facies forming the external part of the ría; biotite granite, which forms a small area in the centre of its northern border and metasediments and gneisses of the Complex Malpica-Tui at the ría back with an transversal enlargement of it and being the output of one of the depressions of etch origin, a satellite of the great Meridian Depression. Until soon, (Fig. 4) a tectonic origin combined with the fluvial erosion common to all these Galician rías was assigned to the formation of the Muros ría (Nonn,
1966; Pannekoek, 1966 a,b), but at present it is considered that the role of the local tectonics has little influence on the generation of the form, which is justified by the lithologic differences. Summarily, the conical relief located at the northern mouth of the Muros ría, Monte Louro, is a magnificent example of residual, therefore primary endogenous form delimited by the structure and its differences of resistance to weathering with the host rock and which has been defined as littoral and literal inselberg (Fig. 16) (Twidale and Vidal Romaní, 2005). It is delimited with irregular extension along its perimeter by a rocky pediment, which has been incorrectly classified as an abrasion platform, as stated in the first stop they are forms corresponding better to an etched surface. However, this surface might have been flooded temporarily at some interglacial maximum but clearly its irregularity and characteristics are not due to marine erosion. At detail scale, it also presents primary endogenous forms as sheet structure, tafoni and gnammas in all its varieties (Twidale and Vidal Romaní, 2005). The whole south (Fig. 17) border of the Muros ría, formed by the reliefs of Barbanza, is another residual of the Main Surface, where, as the previously mentioned of A Ruña, big and extended screes of periglacial origin are very frequent.

Figure 17. Tafoni de Monto Louro

Stop 4: Chaguazoso. Serra de Queixa. Cabeza de Manzaneda (Ourense)

The objective of this stop is to observe the effects of the Pleistocene glaciarism in this zone of Galicia. Geologically, the area belongs to Galicia-Tras-Os-Montes domain (Barrera et al., 1989). Only in the NE part, the Asturoccidental-Leonesa area is represented. Geologically, it is an old territory but its relief is rejuvenated (widespread incision, dismantlement of the plains, fragmentation of the territory). The reconstruction of the morphogenesis has not been based on
stratigraphic approaches because there exists a sedimentary hiatus between the Upper Palaeozoic and the Middle Miocene, and between the Pliocene and the Pleistocene (Vidal Romaní, 1996).

Eight different plains (Fig. 18) have been recognized between the heights 1800 m and 100 m a.s.l. Its distribution has no equivalent areas and we interpret its extension proportional to the lasting of the morphogenetic process to which they correspond. The most extensive plain would be the R600, Superficie Fundamental (Main Surface) in the sense used by Martin Serrano (1989). Three types of surfaces have been distinguished for its origin: those of glacial erosion (R1400), fluvial erosion (R1200, R1000 and R600) and etch origin (R1600, R 1400, R800 and R400). The analysis of the spatial extension of the plains reveals: the main areal extension of the surfaces R600 (24.7%) and R1000 (10.9%); the notable size of the grabens (11.9%); and an advanced state of degradation (slopes and valleys, 40.7%). From these 8 surfaces we will only look at two: R1600 and R 1400 as it is exclusively in them where we may see the effects of the Pleistocene glaciations set over the generalized weathering processes for the whole area and of supposed Tertiary age.

The Surface of Serra de Queixa (R1600).

This plain is well preserved in the northern border of the Serra de Queixa-San Mamede (Cabeza de Manzaneda, 1781 m) where it is defined by a net step (NW-SE) at the N of which only some very degraded remains of the R1600 are identified. In the southern border of the mountain range, this plain is very degraded (Altos de Ganzedo, 1330 m). The western border is marked by a NE-SW structural alignment and has been narrowed and dismantled heavily by the Návea River to get the plain. The eastern border would be characterized by a sequence of reliefs, progressively degraded towards the SE, strongly affected by the fluvial network (Montes do Invernadoiro, 1550 m; Brotaias, 1532 m). These reliefs are terraced, until connecting with the surface of La Gudiña-Viana do Bolo (R1000). On the whole, it can be supposed that the contour of the erosion plain would be defined by two systems of fractures: NE-SW, the main one; and NWSE, subordinate to the first one. Both systems would have dislocated the plain in some moment of the Mesozoic or of the Caenozoic. The granite rocks mark culminating heights (Cabeza de Manzaneda, 1781 m, the Majadales, 1750 m) and they would be the residual of a previous surface. Regarding the morphogenesis, the general development of a regolith and the numerous residuals (castle koppes and tors) allow to attribute an origin by etching to this surface. The preservation of etch forms as vasques (gnammas), in the castle koppes of the Alto de San Mamede, and of patches of the original regolith would indicate that, at this point of the massif, the glaciarism would not have been developed during the Pleistocene (Vidal Romaní et al., 1994). Nowadays, the lingering erosion of the Návea River would have dismantled the initial surface until the degree of emptying and reducing it to the sole perimeter. So, only a residual would have been preserved in the central area (Altos do Acebral, 1606 m). On its surface striking block fields of periglacial origin are preserved and that, due to their position, are contemporary with the development of the glacial episodes characteristic of the lower level, giving a character of supraglacial relief or nunatak to the upper part of the Serra de Queixa.
Figure 18. Map of the eight plains differentiated at Serra de Queixa area.
The Surface of Chaguazoso (R1400).

This plain is interpreted as a lower step of the R1600. It is identified both in the area of Queixa (Llanos de Chaguazoso; Portela das Merendas, 1400 m; Serra do Fial das Corzas, 1400 m; and Altos do Gancedo, 1300 m) and in San Mamede area (As Donas, 1279 m; Lombo dos Gavianes, 1360 m; and O Marco; 1400 m). Towards the E, it could be correlated with the western slope of the Serra do Eixe (Llanos de Lamalonga, 1445 m; and Serra do Cañizo, 1469 m). Towards the S, there may be seen the summit surface of the Serra de Gerez-Xurés (1556 m), another Pleistocene glaciated area with a chronology similar to the one of Serra de Queixa. The incision of the Návea and Camba rivers would be correlated with extensive terrace remnants that would denote an old fluvial network, with a centripetal organization from the Serra de Queixa. Concerning the morphogenesis, the partial preservation of the original regolith would enable to assign the plain an origin by preglacial etching. On the contrary, the dismantlement of the regolith would be related with the Pleistocene glacierism, favoured by the protected position of the plain for the snow accumulation regarding the dominant winds in the area of Chaguazoso (Hernández Pacheco, 1957; Vidal Romaní & Santos, 1994). We understand that the weak convexity of the plain in the area of Chaguazoso is due to the Pleistocene glacial erosion.

Figure 19. Geomorphologic cartography of the glaciated area of Serra de Queixa with dated sample positions with the obtained cosmogenic ages.
Cosmogenic 21Ne dating techniques: applications to granitic glaciated surfaces of Galicia (NW Spain).

One of the main problems in the study of geological processes is to establish their chronologies. Traditional dating methods rely on the sedimentary records and use relative or rarely absolute dating methods. There are many geological processes where erosion dominates over accretion, which make it difficult to place the corresponding exogenic processes in a temporary sequence. Most of the surface of Galicia, NW Spain, is bare erosive surfaces to which geomorphologists attribute a “geomorphological age”, generally imprecise or approximate and does not necessary correspond to the real age of a surface (Watchman & Twidale, 2002) for different reasons. Dating of geomorphological erosion rates and events is virtually imposible except by using the nuclides generated as products of the interaction of cosmic rays, called cosmogenic nuclides. Secondary cosmic rays produce new in situ nuclides, both stable and radioactive, on the exposed surface. The nuclide accumulation on the surface depends on the surface stability and properties of the generated nuclides. The early studies of cosmic ray reactions in meteorites and on the lunar surface became common tools for planetary science. Today, this technique has been applied to Earth’s surfaces of quite different geomorphological histories and many studies have been published. Undoubtedly, the classical work deals with the Pleistocene glaciations, in calculating the exposure ages of glaciated surfaces and moraine of glacial systems.

In Galicia these criteria were followed by selecting surfaces with a clear origin by glacial erosion (Serra de Queixa). The glacial processes acted over a brief span of time, forming surfaces that later were exposed to cosmic rays. In the glaciated areas, the presence of microfeatures of glacial polish is the better proof of a small or null erosion rate after its exposure. In the glaciated areas, the certainty that the erosion has been low judged from the ice ablation allows to date this moment in each one of the sampled surfaces (see table 6). The obtained exposure ages are coherent with the geomorphological hypothesis that assigns relative chronologies in each of the studied glacial systems (Vidal Romaní & Santos 1994; de Brum et al., 2000), and demonstrate a true synchronism between two independent systems. Moreover, these ages relate these systems to the global glaciation events represented by the isotopic stages 2, 6 and 8, in which they are comprised (Vidal Romaní et al., 1999; Fernández Mosquera et al 2000).

The first works on the Pleistocene glaciarism of the NW of the Iberian Peninsula have more than a century (Hult, 1873, 1899; Fraga et al., 1994), though they are mere morphologic descriptions. Obviously, the Pleistocene glaciations of the NW of the Iberian Peninsula were always developed on a same surface approximately. During every stage of the glacial advance what had been deposited or eroded previously has totally or partially disappeared, and the preserved prints of the glacial dynamic are a mixture of deposits and erosive features without another distinctive chronological criterion than the one of the superposition. No absolute datings were made in any of the previous works, but most of the authors implicitly accepted that the described glaciarism corresponded to the Würm. Also, in these works, the Würm was considered implicitly or explicitly as the coldest period in the NW of the Iberian Peninsula. Only some author (Hernandez Pacheco, 1957), for certain case (Serra de Queixa, Ourense) states the existence of an older glacial phase, that associates, without dating, to the Riss though accepting it implicitly, as the coldest episode, or at least the most productive in ice when recognising an advance of the glacier fronts superior to the previous ones. This datum is especially significant as this author (Hernandez Pacheco, 1957) based his dating (relative) on the criterion of the conservation grade
of the moraine, very deteriorated. According to him it was the oldest one. In fact, the oldest moraine was an accumulation of little height, very sparse along a wide area. The comparison of this moraine with the next one (and subsequent in time and space) much higher (there have been counted up to 30 m of height) shows different characteristics. Up to very recent dates (Vidal Romani et al., 1999), it has not been stated that this moraine should not have been formed in only one episode of glacier advance (Hernández Pacheco, 1957), but in successive advances (so explaining its greater dimensions and better conservation).

The geomorphologic data (Vidal Romani & Santos, 1993; Vidal Romani et al., 1990 A And B; Vidal Romani & Santos, 1994; Vidal Romani, 1996; Grandal et al, 1997; Leira et al., 1997) have caused to think of the existence of a long time between the glacial maximum (corresponding to the most advanced morainic fronts) and the beginning of the deposition in overexcavated depressions, the only place where datable sediments have been preserved (Vidal Romani & Santos, 1993, 1994). This interval is partially filled as from the present existing data allow the establishment of an absolute chronology, though reduced to the last 300,000 years for the Peninsular NW using the only technique applicable in our case: the dating by cosmogenic nuclides in quartz crystals.

In the glaciated area presented here Serra de Queixa-Invernadoiro, the substratum is granitic (granodiorite). Also, the area has been already strongly altered. The Pleistocene glacial erosion (Vidal Romani et al., 1990 a, b) firstly contributed to eliminate the regolith and then to erode the rock in successive phases. At the end of every glacial advance phase, the following ablation left broad rocky areas exposed to cosmic radiation. All this allows to considering as reasonable hypothesis that the rocky surfaces exposed by the glacial erosion, firstly as consequence of the edaphic degradation, and then because they are covered by the glacial ices, did not initially have any cosmogenic component accumulated in the analysed quartz. The one afterwards accumulated is subsequent to the rock exposure during the glacial ablation stages.

Stop 4a: Q-1
Coordinates: 42º15’427N
7º17’967W
Altitude: 1778 m
$^{21}$Ne production rate: 76.8 at/g (Si) year
Lithology: granite
Surface type: etched surface
Geomorphologic position: supraglacial
Geomorphologic age: Mesozoic (?)

The sample was taken from a granite (Fig. 20) sheet surface located in the top of Cabeza de Manzaneda, near the geodesic vertix. It was affected by a very active dry periglacialism during which the rock was on surface and not covered by a soil.
Figure 20. Location of sample Q1.

**Stop 4b: Q-2**

Coordinates: 42º10’087N 7º12’069W
Altitude: 1210 m

$^{21}$Ne production rate: 48.6 at/g (Si) year
Lithology: granite
Surface type: block
Geomorphologic position: frontal moraine
Geomorphologic age: preserved local maximum. Medium-upper Pleistocene or “Riss”

The sample was taken from (Fig. 21) one of the large blocks corresponding to the frontal moraine that marks the maximum glacial advance in the Chaguazoso area. The rock is the granodiorite of Queixa with some mafic mineral concentration.

Figure 21. Location of sample Q2.
**Stop 4c: Q-3**
Coordinates: 42º11’052N 7º 13’ 083W
Altitude: 1294 m
$^{21}$Ne production rate: 52.06 at/g (Si) year
Lithology: granite
Surface type: glacial polish
Geomorphologic position: drumlin surface
Geomorphologic age: stage of medium deglaciation, Upper Pleistocene or “Würm”.
The sample (Fig. 22) was taken from the top of a drumlin once having crossed the Cenza River, before reaching the back of the Dam of the Cenza River. The rock is a feldspatic pegmatite.

![Figure 22. Location of sample Q3.](image)

**Stop 4d: Q-4**
Coordinates: 42º12’831N 7º 15’ 448W
Altitude: 1340 m
$^{21}$Ne production rate: 54.0 at/g (Si) year
Lithology: granite (Q-4 and Q-4 split2) and quartz (Q-4 Qtz)
Surface type: glacial polish surface
Geomorphologic position: drumlin surface
Geomorphologic age: stage of late deglaciation, Final Pleistocene or final “Würm”.
The sample (Fig. 23) was taken from the top of a drumlin complex, just behind the cerrada of the Dam of the Cenza River. It would correspond to the most frontal part of the complex.
Stop 4e: Q-5
Coordinates: 42°12′302N
7° 15′ 508W
Altitude: 1516 m
21Ne production rate: 62.2 at/g (Si) year
Lithology: mylonitic granite
Surface type: morainic block
Geomorphologic position: frontal moraine
Geomorphologic age: preserved local maximum. Medium-upper Pleistocene or “Riss” Alto de Pioreta Surface of morainic boulder (Fig. 24) belonging to the local glacial maximum advance.
Stop 4f: Q-6
Coordinates: 42º 11’ 500N
7º 16’ 0108W
Altitude: 1450 m
$^{21}$Ne production rate: 59.0 at/g (Si) year
Lithology: granite (s.l.)
Surface type: morainic block
Geomorphologic position: side moraine
Geomorphologic age: end of the difluence between Queixa and Invernadoiro. Medium Pleistocene.
Granite sample (Fig. 25) from the top of a boulder belonging to a lateral moraine that marks the difluence of the glacier to the valley beside.

![Figure 25. Location of sample Q6.](image)

Stop 4g: Q-7
Coordinates: 42º 11’ 500N
7º 16’ 0108W
Altitude: 1450 m
$^{21}$Ne production rate: 59.0 at/g (Si) year
Lithology: mylonitic granite
Surface type: morainic block
Geomorphologic position: side moraine
Geomorphologic age: end of the difluence to Queixa-Invernadorio. Medium Pleistocene
Surface of a morainic boulder of about 2.5 m of diameter (Fig. 26) on the other side of the tope where Q-6 sample is located and about 100 m of distance; it also marks the glacial difluence to the Invernadoiro area.
Stop 4h. Q-8
Coordinates: 42º 12’ 040N
7º 16’ 110W
Altitude: 1370 m
$^{21}$Ne production rate: 55.3 at/g (Si) year
Lithology: quartz
Surface type: glacial polish surface
Geomorphologic position: drumlin
Geomorphologic age: final stage of the deglaciation. Upper Pleistocene
It corresponds to the most inner part (FIG. 27) of the glaciated area, behind the dam of Chaguazoso.
References


ROAD LOG:
1st Day
Departure from University Institute of Geology (A Coruña) 8.30

0-22 km A-55 Motorway to Carballo city.
22-87 km Local road to Laxe village. Coffee stop at “Mareas Vivas” cafeteria.
87-105 km Local road to Ponto do Porto. Stop at the junction with the track that goes up to Arou. A 30 minutes walk along a track to Cementerio Inglés (Stop 1). Stop at a panoramic point to see the main geological and geomorphological features of granitic coast: abrasion platforms, climbing dunes, blow out dunes, shingle beaches and weathering profiles at present sea level. Observation of granitic geomorphologic features: tafoni, gnammas and etched surfaces.
105-110 km The coach will take us to Cabo Vilán lighthouse. Panoramic view of the coast.
110-115 km The coach will take us to Villa de Oro Restaurant for lunch.
115-125 km Local road to Vimianzo. Visit to the Medieval Castle of Vimianzo.
125-162 km C-552 road to Corcubión and Lézar. Stop 2. Stop at a panoramic point to see the main geological and geomorphological features of granitic landscape: river incision, granite platforms and geomorphologic features: tafoni, gnammas, sheet structure. Xallas Fall.
162-192 km C-552 road to Louro. Stop 3. Stop at a panoramic point to see the inselberg of Monte Louro and the lagoon of Arena Maior, and the main features of the Muros Ría: abrasion platforms, huge residuals of Barbanza with remains of the Main Surface of Galicia.
192-202 km C-552 road to Muros de San Pedro. Expected arrival time at “El Capitán” hotel at 20:00.

2nd Day
Departure from the “El Capitán” hotel at 8:30
0-71 km C-550 road to Noia. Coffee stop at O Ceboleiro. During this way we will stop to see different aspects of the Muros Ría. Then, C-543 road to Santiago de Compostela. Sightseeing of the city and monumental buildings (Cathedral, etc). Lunch at “Don Gaiferos” Restaurant.
71-182 km C-525 road to Ourense. Visit of the thermal springs. Coffee stop at “San Martín” Hotel.
182-255 km A-52 Motorway to Verín. We will see the Tertiary basin of Xinzo de Limia. Dinner and night at the “Parador Nacional de Verín”.
Expected arrival time at “Parador de Verín” at 21:00

3rd Day
Departure from the “Parador Nacional de Verín” at 8:30
0-63 km A-52 Motorway to Alto do Cañizo and take C-533 road to Viana do Bolo. Coffee stop at “Galego” coffee shop.
63-73 km Local road to Chaguazoso. Stop 4. We will see different morainic fronts and subglacial sedimentary facies during 3 hours approximately.
73-93 km Local road to Puebla de Trives. Lunch at “La Viuda” Restaurant.
93-113 km  Local road to Monte Furado. Stop to see the Roman exploitation works of alluvial deposits of Monte Furado.
113-298 km N-120 road to Friéira and C-546 to Nadela. Then A-60 Motorway to La Coruña. Expected arrival time at Riazor Hotel at 21.00

4th Day
Departure from Alvedro Airport (La Coruña) to Madrid at 11:10 by air. Then, flight from Madrid to Zaragoza at 14:30. Arrival time 15:30. A coach will take us to the Conference hall at 16:30.