HIDDEN SURPRISES AMONG THE PYRENEAN TURBULENCE

Roger Lawley

We first toured Northern Spain in the Spring of 2004. High on our list of priorities was to visit the Archaeological Centre at Altamira, the location of wonderful Cro-Magnon Rock Paintings, and now an important exhibition centre for evidence of Early Man. It proved to be a very informative and stimulating visit. I had become interested in the subject matter of the redistribution of *Homo sapiens* following the last Ice Age. Maps indicated that there are numerous cave painting sites to the North and West of the Pyrenees, but apparently none of significance immediately to the South. On the face of it, conditions appear to be fairly similar. I was later to conclude that not much archaeological investigation has, as yet, been carried out in this fairly remote section of the Province of Aragon. It is located between Basque country to the West and Catalonia to the East. It was ravaged by civil war in the 30s and 40s and until quite recently, it has been a bit of a 'no go' area for foreigners, because of the activities of Separatist Groups.

Our Guide Book was rather light on detail as to what we could expect to find there. However, the distributors of EEC funds appeared to have identified the 'needs for development' in this remote area of Spain, and good roads have more recently been imposed on the turbulent terrain. Wild flowers of great variety and colour had clearly ventured into the area at some earlier stage, presumably with the easing of the last Ice Age, some fifteen thousand years ago. This was approximately the time of the cave paintings at Altamira, and at many sites on the northern side of the Pyrenees such as those near Foix.

Driving into the area, for us, was like stumbling on Shangri La. The area was bathed in warm sunshine and the line of snow-capped peaks stretched as far as the eye could see. We were to find, however, that not all was what it initially appeared to be. On that first trip, we identified but did not stay at an attractive looking hotel in the town of Torla, fronting on to the beautiful mountains of the Ordessa National Park *(photograph 1)*. We spoke to and obtained a hotel brochure from its owner Miguel, and assured him that we would be back.

We did in fact return the next year, and the production of a crumpled brochure, with his name written on it, resulted in a warm welcome from Miguel. He proved to be a man of great interest. Trained as an Archaeologist, he said that his pursuit of early human activities was largely confined to the winter months, when visitors to his hotel were scarce. In recent years he had concentrated his investigations on a nearby ruined medieval monastery. He was a fund of knowledge and intelligent comment. However, he could shed little light on the possibility of Cro-Magnon paintings in the area, though he did direct us to some rather more recent rock paintings to the South.

Photograph 1: View of the Mountains in Ordessa Park from the Town of Torla

On our visit to the area in 2006, we were perhaps a little more penetrating in our observations. On one particular day, we climbed up to the spectacular castle site at Boltana. It was sign-posted as 11th Century, so we anticipated that it would be Moorish in origin. The brickwork construction was indicative of Arab workmanship. On our return to the Town Information Office, we sought confirmation from the Spanish lady that it was indeed Moorish. She looked rather shocked at the suggestion and appeared to be of the school which doubted that the 'infidel' had ever been in the area. We asked the same question of the helpful lady at the main centre in Ainsa, whom we had thought might be of Moroccan origin. She was very interested in our views, though we subsequently worried that she might get into trouble if she passed them on to her superiors within the Tourist Office. Miguel's response, on the other hand, when we questioned him in the evening, was that 'of course it was Moorish.'

We also asked him about some abandoned villages we had observed further down the valley, and which appeared to be related to a partly constructed dam. He told us that the project had been stopped during the Civil War. It was his view that work at the site had not subsequently been resumed, on the basis that it was against the will of the country folk, who by that time had had enough of 'exploitation by power-hungry bureaucrats from Barcelona'. The dam site itself was a spectacular one, with twisted rock bands largely spanning the gorge area, and providing what appeared to be a very economic construction site *(Photograph 2)*. However, I was a bit suspicious of its suitability because of the presence of extensive limestone, which, if Karstic, would pose severe risks to water tightness. During the course of the trip, I was to get sight of geological mapping of the area, which

Photograph 2: Location of an abandoned dam site on the River Ara

indicated that a major fault crossed the potential dam reservoir basin and, in all probability, connected with adjacent river valleys. I then had serious doubts about the water tightness features of the site and suspected that with increased geological understanding, which had become possible in the second half of twentieth century, the investors had considered it unwise to proceed with construction of a dam in that location. I did not convey my views on the subject to Miguel.

Limestone was very prevalent in the area of the Ordessa Park, presumably coming from the coastal basins, which had become elevated with the relentless push from the South. We were to see some very impressive exposures of folded and displaced strata which I had assumed were associated with the Alpine Orogeny some 25 Ma, *(Photograph 3)*

Photograph 3: Rock exposure in the Canyon area of Ordessa Park

However, I was to learn that mountain building in the Pyrenees goes back to the Variscan Orogeny, perhaps some 290 Ma. Our enquiries in the Ordessa Park had confirmed that the relatively horizontal strata to be seen at a high elevation in the centre of the Park, (*Photograph 1*), was indeed limestone, but we were not able to gain a detailed understanding of the mechanics for what must have been complex processes of folding and thrust.

In the latter part of the holiday, we moved further East to the area of the Aiguestortes National Park, which is in the province of Catalonia. We had sought a modest hotel in the village of Espot, which is located on a direct access route to the Park. We debated for some time about the apparent merits of two quite adjacent hotels. Having entered the one of our choice, I was surprised that the lady at the desk in fact went across the road to the other hotel to summon Eduardo, the owner, who dealt with us thereafter. When we made enquiries about an attractive restaurant, which we had observed in the vicinity, we were to learn that Eduardo was again the owner.

The next day, we set off for the Aiguestortes Park. As for Ordessa, it was only permitted to drive to an adjacent car park, and thereafter it was necessary to walk. Initially, we seemed to be alone in the world and the scenery was magnificent *(Photograph 4)*. Jagged peaks of what l took to be limestone outcrops, surrounded the valley.

Photograph 4: Mountain scenery in Aiguestores Park

At one point, we chatted with an elderly English couple, who were on their way back down the valley. It would not have been any good asking their views about the Geology of the area, as their gazes were firmly directed below the horizontal. They were identifying the wild flowers and announced that they had just spotted Gentians, for the first time that day. On parting, they told us to look out for Azaleas further up the valley. This did not seem right to me, as every ‘gardener’ knows that that type of plant will not thrive in limestone conditions. This made me look more carefully at the surrounding rocks and I noticed that the boulders near the path were in fact granite. I then wondered if the spectacular peaks around us were in fact composed of igneous and metamorphic rocks, much older than those we had been seeing at Ordessa.

Back in the hotel that evening, I noticed for the first time the fabulous orange-coloured marble staircase, which might have graced a stately home in UK, rather than a modest hotel in the back of beyond. We then started to become aware of marble everywhere, with attractive slabs even serving as paving stones.

A walk around the village produced no more surprises, until we were nearing the hotel on our return. We spotted a Spanish geological book among the post cards and tourist bric-a-brac on display in a shop window. A notice said that you should ring the bell if you wanted attention. It came as no surprise to us, to find that it was the nice Eduardo who came to open the door. When we looked carefully at the surrounding area of human habitation, it was quite clear that we were in deed within a single strata (perhaps Eduardozite?), in that corner of the town of Espot!

We resolved to brush up our technical Spanish and study our newly-acquired geological book, with the object of returning another year to seek more answers to the riddles of the Pyrenees.

GEOLOGY OF SPAIN

Elizabeth Devon

Roger and Joy Lawley, members of Bath Geological Society, are planning to lead a visit for the Society to the Spanish Pyrenees in May 2007. We shall be visiting sites mostly in the Ordessa and Mount Perdido National Park.

We shall be travelling from Barcelona to the south-west of the Catalonian Coastal Ranges, through the Ebro Basin north to the Pyrenees. The Catalonia Coastal Ranges are formed from Palaeozoic (Variscan) inliers and Palaeozoic and Precambrian rocks of the Iberian Massif. The Ebro Basin contains Cainozoic sediments with little or no Alpine deformation. Once we reach the Pyrenees we shall be travelling over Mesozoic and Cainozoic sediments deformed by the Alpine orogeny.

The geology of Spain is remarkably diverse and includes one of the most complete Palaeozoic sedimentary successions in Europe and an excellent record of the effects of the Variscan orogeny on the margins of the super-continent, Gondwanaland. Post Variscan Mesozoic and Cainozoic strata are widely exposed across the eastern half of Spain from the Pyrenees to the Balearic Islands. These successions and their fauna reveal a unique Iberian palaeogeography influenced both by the widening of the Atlantic to the west and by the events in the Tethys Ocean and Alpine-Himalayan orogen (mountain belt) to the east. Alpine collisions in Cainozoic times have created spectacular mountain belts in which the effects of both collisional and extensional processes can be observed. Neogene and Quaternary volcanism has occurred in southern, south-central and eastern mainland Spain and the magnificent Canarian volcanoes expose one of the world's classic hot spots related to ocean island chains, similar to Hawaii.

The Alpine structures in Spain are rather complex compared to other European foreland areas. This is a consequence of the Iberian peninsula being a small continental plate, which, after the Variscan orogeny, moved relatively independently of its two great neighbours, the European and African plates. The most important Alpine range, the Pyrenees, was formed along the northern limit of the Iberian plate with a north-south shortening direction.

The Pyrenees is a mountain range produced by tectonic inversion of Mesozoic rift systems. This rifting was associated with the fragmentation of southern Variscan Europe and western Tethys as a result of the break-up of Pangaea, as well as with the opening of the central Atlantic Ocean and the Bay of Biscay, and the resulting rotation of Iberia. The Pyrenees form a doubly convergent collisional mountain belt which resulted from Mesozoic-Cainozoic interaction between the Afro-Iberian and European plates. Convergence occurred from Late Cretaceous (Santonian) to Middle Miocene times. As a result the earlier extensional structures were firstly inverted, then incorporated into the thrust system.

The area is part of a larger mountain belt extending for some 1500km from the eastern Alps along the Mediterranean coast to the Atlantic Ocean NW of the Iberian peninsula. The Pyrenean mountains are flanked by two main foreland basins, the Aquitainian basin in the north and the Ebro basin in the south, and they display different characteristics along strike. In the east, the Pyrenean mountains have been overprinted by Neogene extensional features related to the opening of the Gulf of Lyon and the drift of the Corso-Sardinian block. In contrast, the main part of the mountain range between France and Spain forms a continental collision zone without this late extensional overprint. Here the mountain belt developed over a previously thinned continental crust but without intervening oceanic crust between the two plates.

The size of this linear range of mountains, the quality of exposures and the unusually good preservation of the strata and its structures make the Pyrenees an excellent natural laboratory for investigating mountain-building processes and foreland basin formation mechanisms.

The Pyrenean range can be divided into two main parts: the Aragonese-Catalan Pyrenees (subdivided into eastern, central and west central) and the Basque-Cantabrian or western Pyrenees. The boundary between the two parts corresponds to an inverted Early Cretaceous transfer zone known as the Pamplona Fault.

We shall be visiting an area within the Aragonese-Catalan Pyrenees which forms the main part of the mountain belt and defines the Spanish/French border.

It is characterised by a thrust system that displays an asymmetric double wedge of upper crustal rocks. This double wedge divides the mountains into the northern and southern Pyrenees. The southern wedge, where we shall be, is formed by a southward-directed imbricate stack involving cover rocks (south Pyrenean thrust system) and basement rocks (known as the 'axial' zone).

The geology and landscapes we shall see are spectacular. I hope we shall be able to work it all out when we are there!

THE DRYING UP OF THE MEDITERRANEAN

Reg Bradshaw

The long history of the Earth - some 4500 million years, has been elucidated by looking at rocks, at what they are made of and what they contain. This investigation began with speculation, then by looking followed by further speculation, then by detailed examination of rocks in the field and finally by applying a wide variety of experimental techniques in the laboratory. Still today, however, one has first to explore and discover the specimens before they can be subject to this vast array of tests. A major step forward has been the ability to study the behaviour of materials under conditions of high temperature and pressure which obtain at deep levels within the Earth.

We have become accustomed to seeing, on television, models of continents moving rapidly (geologically speaking) over the surface of the globe and ramming into each other to form mountain ranges, to asteroids impacting on the Earth bringing widespread death and destruction, to global changes of climate and of sea-level, to long-continued and catastrophic volcanic eruptions, and so on - the list is very long.

One relatively minor but intriguing story is that of the drying-up of the Mediterranean and more recently of its overflowing into the Black Sea and the surrounding lowlands. But first a bit of geography, so please refer to an atlas. Several million years ago, the Mediterranean was part of a broad seaway linking the Pacific and Atlantic oceans. The coming together of Europe and Africa eventually severed this connection though maintaining a link with the Atlantic through the Straits of Gibraltar. This link enabled world-wide oceanic waters to enter the Mediterranean and maintain its saltiness. At its eastern end the sea has connections with the Black Sea through the Bosphorus. A number of rivers, particularly the Nile, Rhône and the Danube, bring in fresh water but in small volume compared with the volume of the sea which in some places reaches a depth of 3000 metres.

From about 1830 onwards there had been suggestions, based on the nature of fossils, that the environment of the Mediterranean had changed markedly at a date now known to be between 6-5 million years ago. In the 1890s a borehole at Valence in the Rhône valley, 200km from the river mouth, proved a gorge 100s of metres below sea-level cut into hard granite and filled with marine sediments overlain by river sands and gravels. A river can only cut down its bed to sea- level so this suggested that the level had at one time been much lower. Then in the 1930s oil-company geologists working in Libya reported buried channels 400m below sea level and running towards the coast. They proposed a sea level several hundred metres below the present but the 'establishment' refused to publish their results - a not-unusual case if the suggestions do not conform to orthodox thinking! Investigations in Algeria, Malta, Yugoslavia and Israel yielded similar results and finally the Russians, in the 1960s, while carrying out tests for the proposed huge Aswan Dam on the Nile, 1250km from its mouth, found a 250m deep gorge cut into granite with the implication that the river bed where it entered the Mediterranean would have been hundreds of metres below present sea-level

So what might have caused such a dramatic fall and what other evidence might there be? There are mountain ranges in southern Spain and northwestern Africa which curve to join each other across the Gibraltar Straits; the region had a long history of instability and there is much evidence supporting the view that on a number of occasions the floor of the Straits was uplifted, thus cutting off periodically the supply of salt water from the Atlantic. The inflow of fresh water could not keep pace with evaporation so the sea began to dry-up; it has been calculated that it might have taken only 1000 years for this to happen leaving a deep, arid plain or playa flat with a few large saline lakes located where the present deeps are, all 3000m below modern sea-level.

Oceanic/open-sea water has an average salinity of 3.5% i.e. 100 grammes of water contain 3.5 grammes of salts in solution, the common elements being sodium, calcium, magnesium, potassium, chlorine with many others in smaller amounts. When the water evaporates salts are precipitated (just like the scale in our kettles), the least soluble coming out first and the most soluble last. If we take a column of water 100 cm high and heat it up (as in the Mediterranean) then the first mineral, calcite, only appears when half the water has gone; the next, gypsum, when 80% has gone and the next, halite (common salt), when only 10% of water is left. The last minerals are precipitated when only 2% of water is left. The minerals deposited are called evaporites.

'Salt' deposits are known around the Mediterranean but it was only in the 1960s when the Glomar Challenger, an American research ship, was able to drill through 2000m of water into the bottom of the sea to the southeast of Barcelona that evaporites were found and subsequently were found over almost the whole of the sea floor. There are good indications that the sea evaporated almost to dryness.

Above the evaporites are muddy deposits with fossils characteristic of cold bottom waters indicating that the barrier at Gibraltar was breached and the Atlantic flooded in over a waterfall calculated to have been 100 times the volume of the Victoria Falls and 1000 times that of Niagara - perhaps 40,000 cubic kilometres in a year and taking more than 100 years to fill the Mediterranean basin.

And all that and more from looking at rocks !!

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