MEGATURBIDITES IN THE SPANISH PYRENEES

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One of the highlights of a visit, with other members of the Bath Geological Society, to the Spanish Pyrenees organised by Roger and Joy Lawley last May, was the opportunity to study MEGAturbidites. Many of us have seen turbidites in North Devon and West Wales but MEGAturbidites were something new and very exciting - well, I suppose, it does depend on your point of view.

We had been joined on our trip by Professor Andrés Pocovi, a tectonics expert, of the university of Zaragosa and Dr, Carlos Marti a geomorphologist and Quaternary specialist from the Pyrenean Institute of Ecology.

A bit about ordinary turbidites first - - turbidity currents are flows of sediment-laden water beneath a larger standing body of water - the sediment suspended in the water makes it more dense. This denser water remains at the bottom and is able to flow fast downslope. The currents can occur in bodies of water of all sizes, but in terms of scale and volume of sediment transported, they are most important at the ocean margins, including trenches.

The deposits are alternating beds of sandstone and shale - called turbidites (flysch in Spain). The currents are fast flowing and they have enough impetus to travel for hundreds, perhaps thousands of kms across the ocean floors.

Turbidites have sand, silt and mud grades. Most turbidites are poorly sorted and, since turbidite sandstones usually contain more than 15% mud matrix, they are called greywackes. Many turbidite sandstones are immature, even though they have been carried for great distances. There has been no attrition of the buoyed-up particles. Many turbidite greywackes contain more than 25% feldspar and are called arkoses. They may also contain plant fragments or shallow water organisms. Even sands containing glauconite have been found.

The deposits have regular sand-shale alternations and have wide lateral extent and regularity. A typical turbidite sequence was first described by Bouma in 1962 and is now called the Bouma Sequence. Basically, this is as follows:-

The sequence starts on the ocean floor, which is covered with layers of pelagic mud, settled from suspension.
A - after the turbulent turbidite head has passed, deposition begins as the current slows down and the sequence starts with a massive, structureless sand - high flow conditions causes no layering. As the depositing current is slowing down, grain size increases upwards, i.e. grading occurs
B - the slowing current then deposits sand under high flow conditions that produce plane bedding
C - low flow conditions - rippled sand which is seen as cross lamination in cross section
D - laminated sands and silts - last deposit of the current as it disappears across the ocean bed
E - original quiet conditions of settling pelagic mud take over - laminated.

The fast flowing turbidity current passes over the mud and erodes it. A small eddy or vortex will form in the water as it flows over the mud and a series of these produces spoon-shaped depressions in the mud, which widen down current, so called flute marks. Tool marks are produced by 'tools' i.e. bits of debris marking the mud as they move along. These include groove marks - material dragged in mud, prod or bounce marks - bits prodding or bouncing in mud as they pass.

All these sedimentary structures are preserved because sand is deposited from the turbidity current in the depressions in the mud, thus making casts. They are all called sole structures because they are all found on the sole, or base, of the sandstone bed. Other sole structures are produced when tracks and trails of organisms become filled with sand and are preserved as casts.

The whole Bouma sequence is a single bed - it is deposited by one sedimentary event; perhaps one afternoon! It becomes finer from bottom to top, so is graded. All the sedimentary structures are useful way-up indicators.

After the deposition of a turbidite, the sand at the base of the sequence, being more dense than the waterlogged mud beneath, may collapse down into it forming small folds called convolute bedding. The sand lumps are called load casts and the mud which is squirted up between the lobes produces flame structures. These are useful way-up criteria since sediment cannot collapse upwards.

It is rare to have a complete Bouma sequence in one place. Usually, only the divisions from the bottom of the sequence or the divisions from the top of the sequence are found - because the coarser sediments are deposited near the source of the turbidity current, producing thick deposits, whereas the finer material is carried further to produce thinner deposits of e.g. D and E divisions. So thick, massive turbidite deposits develop near the source, i.e. the continental slope, probably as part of the submarine fan. Thin turbidites, comprising only the upper Bouma divisions, are deposited far out in the ocean.

I will get back to MEGAturbidites shortly, but first a quick word about organisms. Organisms are rare - turbidity currents are catastrophic! Some tracks and trails are preserved as sole structures, showing that there was life on the ocean floor. Other organisms associated with turbidity currents have been swept in from shelf areas.

brecciated and slumped limestone

Megaturbiditic limestone cuts across normal turbidite sequence

Normal turbidite sequence

Sketch 1: MEGAturbidite
This was drawn by Prof Andrés Pocovi while we were studying it.

His skill at sketching and, later colouring, what he could see, never failed to amaze us.

Back to MEGAturbidites - - we were based at Torla, which is located at the western end of the stunningly beautiful Ordesa National Park. We explored the general area to the west and saw our first MEGAturbidite to the west of Jaca near the Valle de Hecho, *sketch 1.*

It is one of a series of such structures in this area and is known as No. 5 or Roncal, The normal sand, silt, mud turbidite sequence, typical Bouma C, D. is cut across by a fossiliferous limestone, to the right of the sketch, *photo 1.*

Photo 1: Turbiditic limestone (left) cutting across the normal turbidite sequence

The limestone clearly contained foraminifera and is typical material of a normal deep basin limestone. The following day, we saw the origin of this limestone in-situ to the south of the area, but here it is brecciated and represents a major, (I mean MEGA major) catastrophic event. Towards the top, the beds become more organised as the event passed and there is more and more clay. This MEGAturbidite is 40km long and 200m thick, It dates at c.46Ma (Eocene). This type of deposit is known as an olistostrome slump where a chaotic mass of heterogenous material has accumulated as a semifluid body by submarine gravity sliding. The normal flysch deposits in this part of Spain are east to west, but all the MEGAturbidites come from the south. A catastrophic event of the order of the Sumatran tsunami in December 2005 caused this massive upheaval of limestone.

After seeing our first MEGAturbidite, we set off for Torrijos Bridge to see another. Here the megabeds have been overturned. The series started with a normal turbidite sequence with thick well-stratified beds and then another massive brecciated limestone. From here, we drove further up the road to Castiello de Jaca where there were the best invertebrate trails on the bottom of the sandstone turbidite beds we had seen so far, *photo 2.*

Photo 2: Invertebrate trails at the bottom a sandstone turbidite

The whole week in the Spanish Pyrenees was thoroughly enjoyable with fabulous geology, scenery, flora, some fauna and excellent company. Thank you, Roger and Joy, for organising such a splendid trip.