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Water Tracing in the Vega Huerta Caves, Picos de Europa, Spain

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Abstract: Water tracing experiments using lycopodium spores and fluorescein dye have been carried out in the caves and surface sink near Vega Huerta, in the western massif of the Picos de Europa, Northern Spain. Water from the sump at –986 m in the M2 cave system has been shown to resurge in the Canal de Capozo, 3.5 km to the east. The exact altitude of the resurgence cannot be determined since it is buried by glacial deposits, but the vertical range may be as much as 1350 m. The drainage appears to be controlled by a major fault passing just to the south of the present end of M2, and continuing eastward into the Canal de Capozo. A second resurgence in Capozo, only 100 m from the M2 resurgence, appears to be unconnected and may drain the cave systems immediately south of Vega Huerta.

Between 1985 and 1987 considerable efforts were made to discover the resurgence(s) of the cave systems around Vega Huerta (4°58'W, 43°12'N) in the western massif of the Picos de Europa in northern Spain. This is an area in which York University Cave and Pothole Club (YUCPC) has been exploring, together with the Seccion de Espeleologia de Ingenieros Industriales (SEII) from Madrid (Fig. 1). The two most important caves explored have been the M2 system shown in Fig. 2 (Senior, 1987), with the limit of exploration at -986 m, and, more recently, B3, currently explored to –944 m. The hydrology of M2 is complex, with several streams, whilst B3 has a single active streamway leading to a sump at –944 m. Attempts have been made to trace three underground watercourses:

A. The Vega Huerta stream sink is a surface sink below the path from Vegabano to Vega Huerta, about 100 m before the remains of the Vega Huerta refugio. Although blocked to cavers by boulders, it takes an intermittent summer flow of up to about 5 litres per second from snowfields at the base of the peak Cotalbin.

B. The second streamway to be investigated was that entering M2 in the upper series at Watford Gap. A small, irregular flow of the order of one litre per second is found here.

C. The M2 lower streamway, where the most extensive investigations have taken place. Water is seen below El Gordo until it is lost in the too-tight Nicky's Rift, and also a stream enters the sump at –986 m. The flow is several litres per second.

The relative relief is very great in the area around Vega Huerta (2000 m asl). Three kilometres west-southwest is the gorge of the Rio Dobra, at approximately 1050 m asl. Three kilometres east is the bottom of the Canal de Capozo, a precipitous valley leading into the Cares Gorge and the Rio Cares at 600 - 700 m asl. The bottom of the Canal de Capozo is covered by glacial deposits, hiding the base of the Barcaliente Formation into which the M2 cave system extends. Farias (1983) suggested that the impermeable rocks of the Pisuerga-Carrion Province underlie this area, reaching an altitude of over 900 m at the southern edge of the Canal de Capozo. To the north of the Canal de Capozo, Farias shows the Barcaliente formation extending down to around 780 m asl. Thus waters sinking at Vega Huerta may travel underground over a vertical range of 950 m to reach the Dobra, or 1220 m or more to the Cares. Farias (1983) has identified three faults which pass through Vega Huerta, coming together just to the west of the M2 entrance. The most northerly of these extends eastwards into the northern part of the Canal de Capozo, whilst a branch of the adjacent fault continues into the southern part of the Canal de Capozo. This is illustrated in the paper by Senior (1987a).

Resurgences in the Dobra and Cares Gorges

Possible resurgence caves and streamways where the Vega Huerta waters may appear occur in the Dobra and Cares gorges. These locations, and sites to which dye tests have been made are numbered on Fig. 1, and described below:

1. The source of the Rio Dobra, fed by surface drainage, is near basecamp at Vegabano. Some early tests were conducted in the upper Dobra, about 1 km northwest of Vegabano.

2. There are no major resurgences in the Dobra until a point directly to the west of Vega Huerta. In dry weather the river sinks in its bed here, only to resurge again in a deep pool a few hundred metres downstream. It is not known whether there is any connection from here to any other underground watercourse. Approximately 500 m downstream there is a large cave entrance in the eastern bank of the gorge, 5 m above river level. This is partially choked and apparently no longer active, but there is a small resurgence from a bedding plane just below (summer flow less than one litre per second).

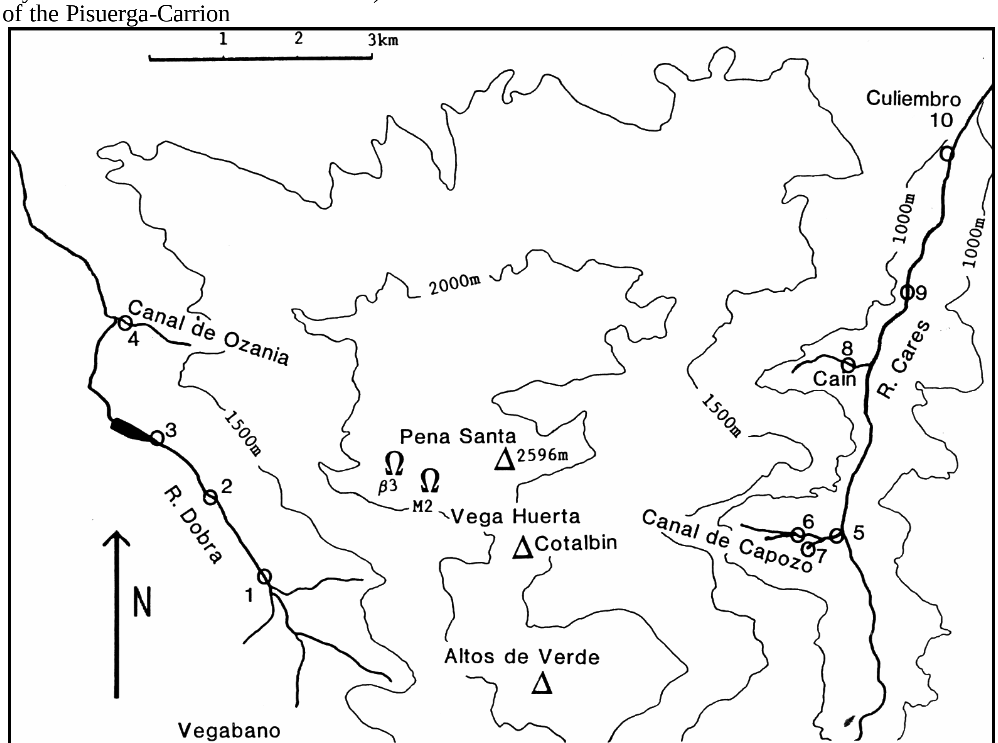

Figure 1. The area around Veg Huerta. o - location of numbered resurgences. D - mountain peaks. W - cave entrances

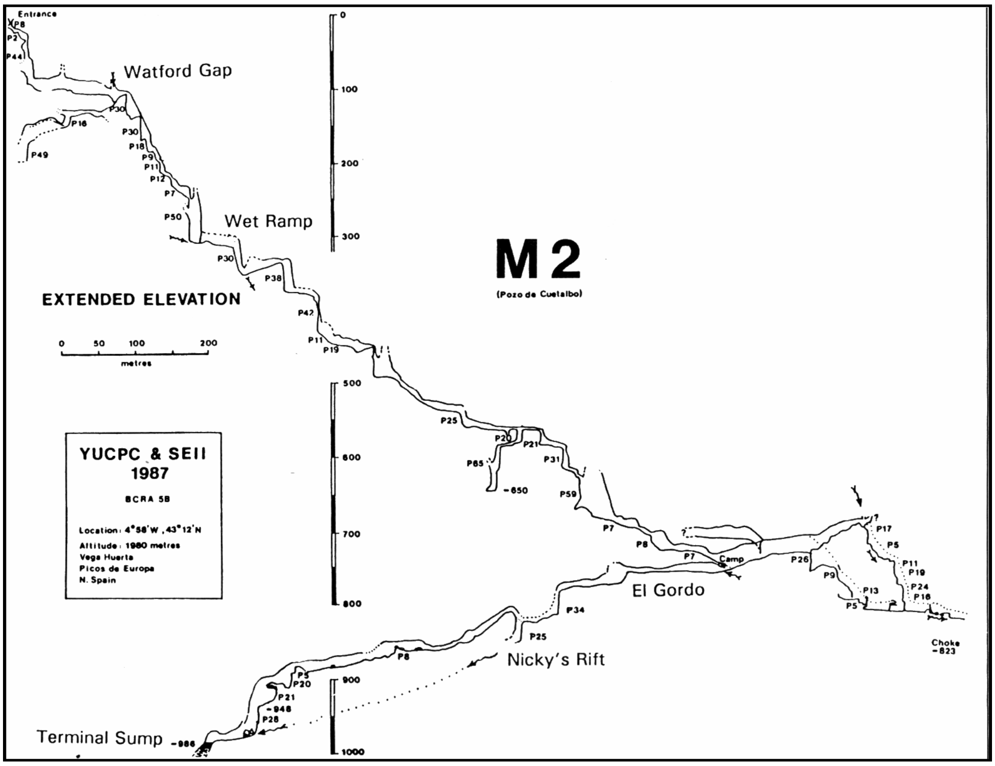

Figure 2. The M2 cave system. Lycopodium spores were used for water tracing from the Wet Ramp and Nicky's Rift. Fluorescein was used for water tracing from Watford Gap and Nicky's Rift. The only confirmed route of flow within the cave is the lower streamway form Nicky's Rift to the Terminal Sump.

3. About 500 m downstream from 2 the river deepens, forming a long lake behind the dam of the Dobra hydroelectric station, which hides any resurgences in this part of the gorge.

4. Just downstream from the point where the track from Amieva crosses the river, a large stream joins the Dobra from the Valle de Ozania. There is one large resurgence amongst boulders near the river, and a further, most spectacular resurgence about 100 m higher, which comes out of a cave 40 m up a cliff face. There are also other small resurgences higher up the valley. The total summer flow from all these resurgences approaches 0.1 cumec. The Ozania resurgences are 3 to 4 km from Vega Huerta.

The Rio Cares runs northward, to the east of Vega Huerta. The river has carved an imposing gorge through the mountains which is at its most impressive to the north of Cain. To the south of Vega Huerta and the Canal de Capozo the river flows over the mainly impervious rocks of the Pisuerga-Carrion Province. To the north it flows over Carboniferous limestones. The closest resurgences to the Vega Huerta cave systems are the group located in the Canal de Capozo, 3 to 4 km away.

5. This site is where the Capozo stream joins the Rio Cares. It is easily found 2 km south of Cain where the road passes over a small bridge across the Capozo stream. In summer the flow is typically 0.1 cumec. Going up-valley the stream quickly bifurcates.

6. Following the northerly branch of the Capozo stream, water flows above ground for some hundred metres or more in summer conditions. There is no resurgence cave, as the bottom of the Canal de Capozo is filled with glacial deposits. The stream simply resurges from its bed over a length of 50 m or more, welling up through sand and boulders. Above this point, the dry stream bed can be followed for nearly a kilometre. There are several tributaries, but the main course goes up above the glacial deposits to the limestone cliffs directly below Vega Huerta. Here there is a finely-sculpted open-air pitch of 20 m, leading up to the steepest part of the Canal de Capozo. To the south is a limestone eliff which forms part of the buttress between the Canal de Capozo and the valley below Torre Bermeja. This seems to follow the line of the most northerly of the Vega Huerta faults. The glacial deposits hide the cave resurgences of the lower Canal de Capozo, so there is an uncertainty of perhaps 150 m in estimating their true altitude. A small resurgence was found in the centre of the buttress in the middle of the Canal de Capozo, but its flow was only around a litre per second, nowhere near the flow seen in the streamway entering the Cares. It is probable that the steeply-sloping bare limestone surfaces in the upper Canal de Capozo allow little chance for water to sink underground, giving rise to rapid runoff, and resulting in the large surface streamways cut into the glacial deposits below.

7. The southern branch of the Capozo stream dries up within 100 m of the road. There is no resurgence cave, again water comes up through cobbles in the stream bed. The dry watercourse extends on up through the woods, headed towards the valley below Torre Bermeja.

8. To the north of Capozo there is a small stream entering the Cares at Cain. It is opposite the impressive Los Molinos resurgence which is fed from the central massif. The stream has a flow of only a few litres per second.

9. Some tests have been performed with detectors placed in the Cares below the dam at Cain. Further downstream there is a small resurgence near the Puente Bolin, again with a flow of a few litres per second under summer flow conditions.

10. Following the Cares at river level revealed no further significant summer resurgences until the large resurgence at Culiembro which Gale (1984) reports to have a baseflow of 0.7 cumec.

WATER TRACING

Both lycopodium spores and fluorescein dye were used to try and trace the Vega Huerta streams. Lycopodium was used extensively in 1985 and 1986. Fluorescein was used for tracing waters within the M2 system in 1986, and for identifying the resurgence in 1987.

Lycopodium was prepared in the manner described by Drew and Smith (1969). The experiments performed using this technique are summarised in Table l. Each test used about 0.5 kg of lycopodium. The result of this work was that all tests proved negative.

Table 1. Water-tracing tests using lycopodium

Year	Sinks	Resurgences
1985	Vega Huerta surface sink; M2 Wet Ramp	1, 6, 8, 9, 10
1986	Vega Huerta surface sink; M2, Nicky's Rift	1, 6, 8, 9, 10

Because of the lack of success using lycopodium, it was decided to try fluorescein dye instead. Fluorescein tracing work was carried out in 1986 to try and find connections between the various cave streamways. Dye detectors were not placed in the cave, as short flow-through times were expected, and visual identification was hoped for. In 1987, fluorescein was the only tracing method used, and it was hoped to find the M2 resurgences in this way. Activated charcoal detectors were prepared, and placed into streams at the beginning of the expedition as controls. These were removed after one to two weeks, before any dye had been introduced into the caves. Fresh detectors were then placed, and the dye test performed. Because of the inaccessibility of many of the test sites the detectors were mostly replaced only once. The test results are summarised in Table 2.

Table 2. Water-tracing tests using fluorescein (and quantities used)

Year	Sinks	Resurgences
1986	Vega Huerta surface sink (300g); M2 Watford Gap (300g)	within M2
1987	M2, Nicky's Rift (3.5 kg)	2-10

In 1986 we were unable to visually detect dye in the lower M2 streamway after placement in either the Vega Huerta or Watford Gap streams. However, dye placed in Nicky's Rift in 1987 was seen within a few hours at the terminal sump, cqnfirming this connection. The large quantity of fluorescein used in this test was due to growing frustration at the lack of a positive trace for M2 in previous year's work. The lack of success with lycopodium suggested that the flow-through time and dilution were likely to be large, which gave some confidence that a spectacular visual trace to the Cares or Dobra would not occur.

The detectors from the 1987 tests were brought back to the UK for analysis. The last set of detectors were recovered some weeks after the expedition left the Picos by members of the SEII. For analysis, 3 g of the charcoal from each detector was heated in 10 ml of 10% KOH in methanol to 60°C for half an hour. The liquid was then decanted off. Fluorescence spectra were measured using an Applied Photophysics fluorescence spectrometer with a mercury arc-lamp light source. The lamp has a predominant emission line at 365 nm, but there are also other strong emissions and consequently fluorescence excitation is not specific. Alternatively, observations were made using an argon-ion laser as an excitation source, with up to 20 mW of light at 454 nm or up to 1 W at 488 nm. Fluorescence was observed visually, either directly or through a narrow-bandwidth interference filter with a half-intensity bandwidth of 7 nm centred at 514 nm. This combination is well matched to the excitation and emission maxima of fluorescein.

The control detectors all gave strong fluorescence spectra, with broad maxima centred around 420 nm. Fig. 3a shows the spectrum obtained for the Capozo control. It does show a very slight deviation from a smooth curve at about 540 nm, close to the fluorescein emission maximum as do several other samples. Presumably this is due to some naturally occurring fluorophore in the water. Using the laser excitation, all three controls gave some faint fluorescence. The Culiembro control gave a white fluorescence, whilst the Capozo and Dobra controls gave a greenish fluorescence. The last two may well have picked up naturally occurring green fluorophores from surface drainage in these heavily vegetated areas (Smart and Laidlaw, 1977). The detectors taken out after the dye had been placed in M2 all gave similar fluorescence spectra to the controls, except for the sample from Capozo (6), which had a significant maxima at 520 nm as well (Fig. 3b), corresponding to the fluorescein emission maxima. This was spectacularly confirmed using laser excitation, when the sample gave a very intense green fluorescence, far brighter than that of any of the other samples. The difference was much more striking than the size of the peak in the spectrum obtained with UV excitation would suggest. This positive trace was obtained from a detector which was removed after the expedition had finished, about four weeks after fluorescein had been added in M2. A detector in the same location which was removed two days after the dye had been added showed no significant difference in its fluorescence spectra to the control. No excess fluorescence was observed from the detectors placed in the more southerly of the Capozo resurgences.

DISCUSSION AND CONCLUSIONS

One of the primary questions concerning the hydrology of Vega Huerta has now been answered. The water in the sump at –986 m in M2 goes eastward and is seen again in the northern Canal de Capozo stream, three kilometres away. The resurgence appears to be associated with the most northerly of the three faults passing through Vega Huerta, with the head of the surface stream bed located on the line of the fault. The time taken to traverse this distance has not been accurately measured, but it is more than two days but less than one month under summer flow conditions. The apparently separate nature of the Capozo resurgences suggests that a perched phreatic network of fractures in the limestone directly behind the glacial deposits in the Canal de Capozo is unlikely. Instead, it seems that flow occurs along a single fault-guided conduit all the way to the resurgence. The southern Capozo resurgence may be associated with the fault passing through Cotalbin, slightly to the south of Vega Huerta, which then runs through the southern part of the Canal de Capozo. This fault intersects an area containing many caves, and may form the main conduit for water from these systems. This could be a very interesting future dye test, which may confirm the presence of two drainage systems within the Canal de Capozo.

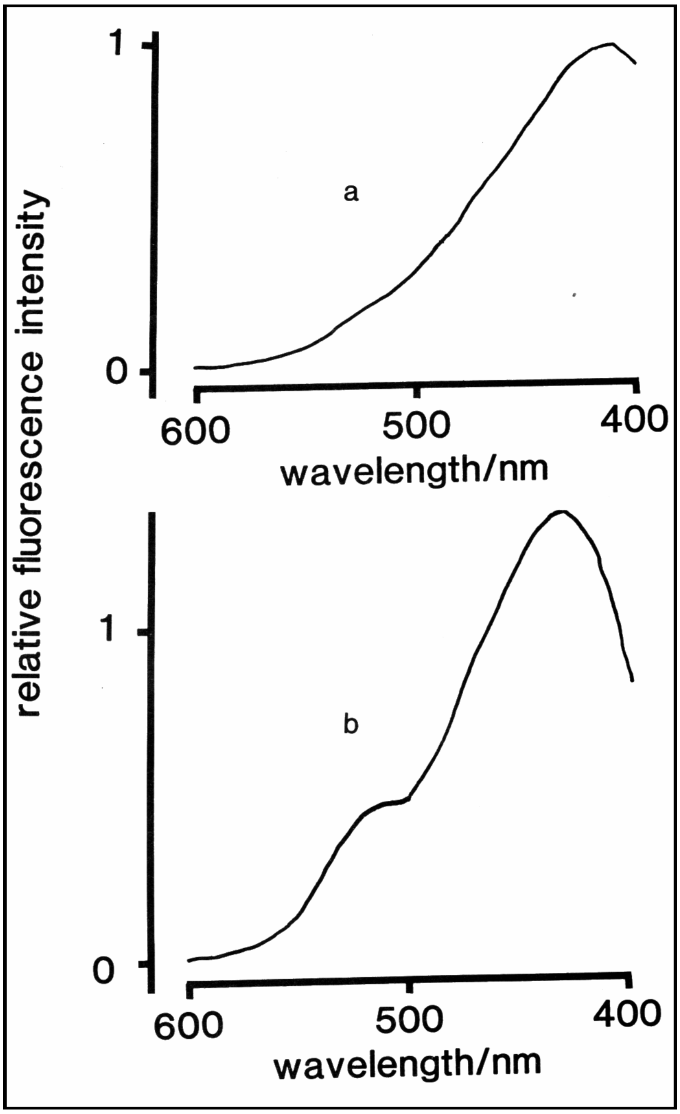

Figure 3. Fluorescence spectra for extracts from two of the dye detectors, obtained with mercuy-lamp UV excitation (365 nm).

a) Spectrum obtained from the Canal de Capozo control detector (location 6).

b) Spectrum from a detector in the same location, one mouth after the addition of 3.5 kg of fluorescein into the M2 streamway at Nicky's Rift. The pronounced maxima at 520 nm corresponds to the fluorescein emission.

The lack of success with the lycopodium traces, and the low concentration of dye eluted from the detector after a trace using 3.5 kg of fluorescein suggest that either collection of the tracer is extremely inefficient, or that the dilution of the cave water might be very great. The apparent separate nature of the Capozo resurgences makes it unlikely that there is considerable ponding of water and dilution behind the glacial deposits at the base of the Canal de Capozo. Also, if it is assumed that the water is guided along the major northern Capozo fault, it would also be somewhat surprising if there was a large, slow-moving body of entrapped water further from the resurgence. An alternative reason may be the fine, sandy nature of the ground through which the water resurges. This may act as a filter for lycopodium, and organic material present may adsorb fluorescein. Also, the dye detectors were in place for a considerable period of time, and so leaching of the dye may have occurred.

Of the other significant streamways which could be tested, the most important are the Vega Huerta surface sink and the streamway entering the sump at –944 m in the recently explored B3 system. On the surface the Vega Huerta sink is very close to the fault which is thought to control the M2 drainage, although the fault running into the southern Canal de Capozo is also nearby. Probably the northern

Capozo stream is the most likely resurgence. B3 lies to the west of M2, even closer to the large Ozania group of resurgences in the Dobra gorge. However, the depth of the B3 system is such that there is less than 100 m vertical range between the lowest Ozania resurgence and the B3 sump, making this an unlikely destination. Once more, the northern Vega Huerta fault appears to be the most likely conduit, taking the water eastward to the Canal de Capozo. If further tests are performed then fluorescent dye rather than lycopodium will be preferred. Green and orange fluorescent dyes should be favoured because of the blue background fluorescence of the Picos waters. The observations made by laser-induced fluorescence were quicker and more decisive than the spectra made with UV excitation. Using the argon-ion laser this technique should be applicable with both fluorescein (454/488 nm excitation) and rhodamine (514 nm excitation). With photoelectric detection the sensitivity of this type of measurement is such that direct quantitation of dye in water samples may be possible, with frequent direct sampling allowing measurements of flow times, dilution, and an estimate of the reservoir volume.

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