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PHYSICO-CHEMICAL STUDY OF THE ANCIENT AND RECENT ACCUMULATIONS OF A BRAIDED SYSTEM (ARA RIVER, CENTRAL PYRENEES, SPAIN)

V. RUBIO*, R. VIGIL, R. GARCÍA & V. CALA**

* *Departamento de Geografía, Facultad de Filosofía y Letras. Universidad Autónoma. 28049 Madrid. SPAIN.*
** *Departamento Geoquímica, Facultad de Ciencias. Universidad Autónoma. 28049 Madrid. SPAIN.*

RESUMEN.- El estudio físico-químico y mineralógico de los sedimentos del río Ara, en el Pirineo Central (España), permite reconocer la génesis y evolución de su cuenca. Los minerales de la fracción arena, los correspondientes a la fracción arcilla y los elementos minoritarios, delatan ciertos procesos y asociaciones que, junto con la identificación de terrazas fluviales, conos, glacis e incluso depósitos morrénicos, ayudan a explicar la historia geológica del Pirineo Central, principal objetivo de este trabajo. La aplicación al conjunto de datos de un análisis factorial multivariante mediante el programa BMDP-4M facilitó la interpretación de los resultados. Los minerales más resistentes se encuentran en las fracciones texturales más finas, mientras que los minerales más alterables se localizan en las más gruesas. Los conos y glacis constituidos por materiales del flysch, presentan una alteración de materiales carbonatados que se manifiesta por la formación de esmectita y sepiolita en la fracción arcilla como resultado de la transformación de feldespatos y anfíboles. También se observa la formación de óxidos de hierro y manganeso con distinto grado de cristalinidad asociados a cromo, plomo y níquel. Las morrenas constituidas principalmente por materiales silicatados conllevan la formación de ilita asociada a cobre y zinc. Por último, las terrazas fluviales tienen mezcla de los procesos de alteración anteriormente descritos.

RÉSUMÉ.- L'étude physique, chimique et mineralogique des sediments de la rivière Ara, dans les Pyrénées Centrales (Espagne) permet de reconnaître la genèse et l'évolution de son bassin. Les mineraux à la fraction sableuse, ceux qui correspondent à la fraction de l'argile et les éléments chimiques minoritaires, démontrent quelques procès et des associations en relation avec l'identification des terrasses fluviaux, des cônes, des glacis et des dêpots morainiques, aident à expliquer l'histoire géologique des Pyrénées Centrales, ce qui est le principal objectif de ce travail. L'application des données d'un analyse factoriel multivariant grâce au programme BMDP-4M facilite l'in-

terpretation des résultats. Les minéraux le plus résistents se trouvent dans les fractions les plus fines, et les minéraux les plus altérables se situent aux plus lourdes. Les cônes et les glacis formés pour les matériaux du flysch, montraient une altération des carbonatés qui finissent dans la formation de la smectite et de la sepiolite à la fraction argileuse comme un résultat de la transformation des feldspaths et des amphibols. Aussi on voit la formation des oxydes de fer et de manganèse avec différent degré de cristalinité, associés au Cr, Pb et Ni. Les moraines formées par les matériaux silicatés conduirent à la formation de l'illite avec le Cu et le Zn. Les terrasses fluviaux montrent une mélange des procès d'alteration avant décrits.

SUMMARY.- *The physico-chemical and mineralogical study of the Ara river sediments, in the Cental Pyrenees (Spain), allows to recognize the genesis and evolution of its basin. The minerals of the sand fraction, the ones corresponding to the clay fraction and the minoritary elements, reveal certain processes and associations that, in addition to the identification of the fluvial terraces, fans, glacis and even morainic deposits, contribute to explain the geological history of the Central Pyrenees, the main objective of this work. The application of a multivariate factorial analysis to the data with BMDP-4M programme was very helpful for the interpretation of the results. The more resistant minerals are found in the thinner textural fractions, whereas the more alterable are located in the thicker fractions. The cones and glacis, composed by materials of the flysch, reveal an alteration of the carbonated materials which is shown by the formation of feldspars and anphybols. The formation of iron and manganesum metal oxides, of different crystallinity degrees, associated with chrome, lead and nickel, is also observed. The morainic deposits, mainly composed by silicate materials, bring along the formation of illite associated wiht copper and zinc. Finally, the fluvial terraces have a combination of both alteration processes previously described.*

Key-words: Braided system, river terrace, clay minerals, microelements, Pyrenees, Spain.

1. Introduction

The purpose of this paper is to study the river Ara in the Central Spanish Pyrenees, assessing the characteristics of the open valley areas, where the river has a large capacity of sediment accumulation asuch as gorges and canyons, which are much more active as far as erosion and dragging is concerned. Is evident that it is in the wide stretches of the river where there are best represented the various levels of the river terrace (HERNÁNDEZ, 1991; HERNÁNDEZ & RUBIO, 1990) and for this reason many of the samples used were collected from these zones, nevertheless, we have also studied the flood plains, the present sand bars and deposits (fans, glacis, etc.).

2. Geographical setting

The river Ara basin is located in the northern area of the province of Huesca (Spain), which is the linking area between the western and eastern valleys of the Central Pyrenees (Figure 1). It has an area of 688 Km^2 including

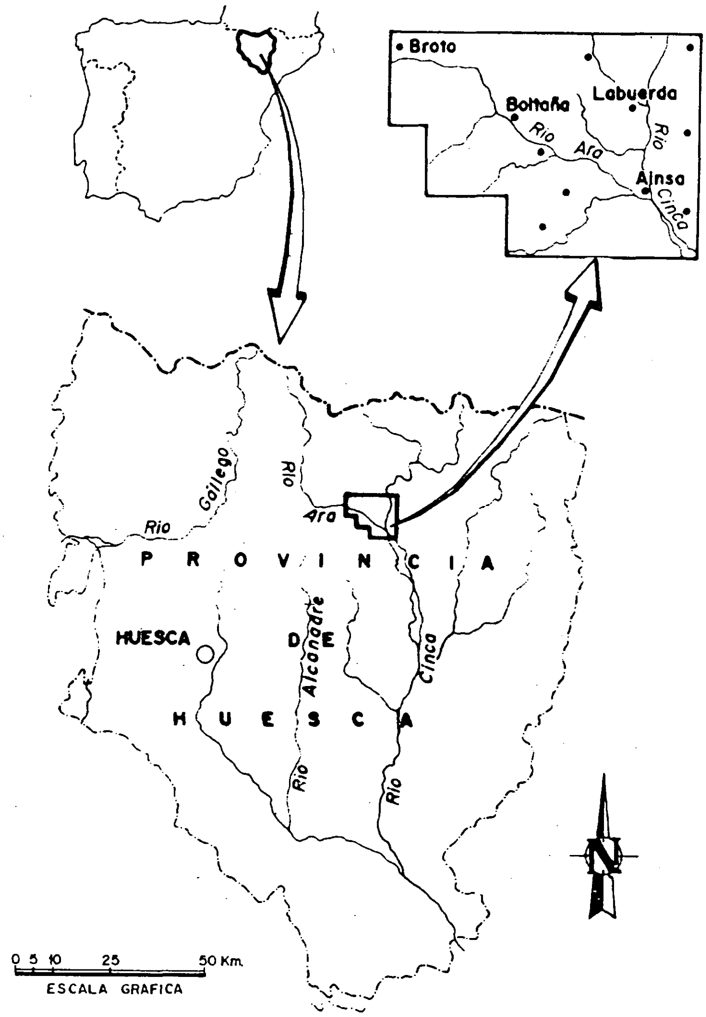

Figure 1. Map of location.
Mapa de situación.

the Vignemale massif, the Ordesa canyons and the ravins located in the Middle Depression. Differences in height of almost two thousand meters, give to the river a great erosive and transport capacity (RUBIO, 1995).

Throughout its course, the river Ara runs through the most important structural and lithological units of the Pyrenees:

- The Paleozoic in the axile zones, with limestones, quartzite and granites.
- The Mesozoic of the Inner Mountain Ranges, basically limestones, sandstones and marly limestones, corresponding to the eastern area of the Tendeñera Range, the forms of the Valley of Ordesa and the massif of Monte Perdido.
- The Cenozoic of the Middle Depression, composed by continuously increasing marlaceous flysch, until meeting the marls of the southern area of the Depression (Aínsa). The latest is broken by the great tectonic accident of the anticline of Boltaña.

From a morpho-structural point of view the only autochthonous sectors are the granitic blocks of the upper part of the basin. The rest of the territory, is formed by several overthrusts toward the South, especially the units of Monte Perdido and Cotiella. At the head there are several overlying folds that have produced an extremely scarped relief. The Cenozoic sector is extremely folded, with an structure that can only be sketched from the presence of sandstone and calcareous megarhythms, as in the North of Aínsa.

Almost throughout all of its course, the river Ara originates a very deep valley, especially between the towns of Broto and Fiscal (RUBIO *et al.* 1996). In the first stretch of the river, the valley is quite deep, being typical of any mountain torrent. But from Broto on and up to its outlet into the Mediano Reservoir (Cinca river), the bed behaves in an irregular manner, which depends on the structural and lithological characteristics that it meets (WEBB, 1994).

3. Materials and methods

Sampling was performed keeping in mind the fluvial morphology. So in Broto the valley opens abruptly due to the weak resistance offered by the flysch and the river, that up to then runs along one channel, now changes into several interweaved beds (braided system). This is the so called contour of Broto, formed by samples Br1 (present sand bar), Br2 (morain) and Br3 (flood plains) (Figure 2).

In the area of Fiscal, after a new narrowing of the valley, the river acquires more energy, thus increasing its erosive capacity and develops very few important terraces. It is after this stretch where the valley increases its width

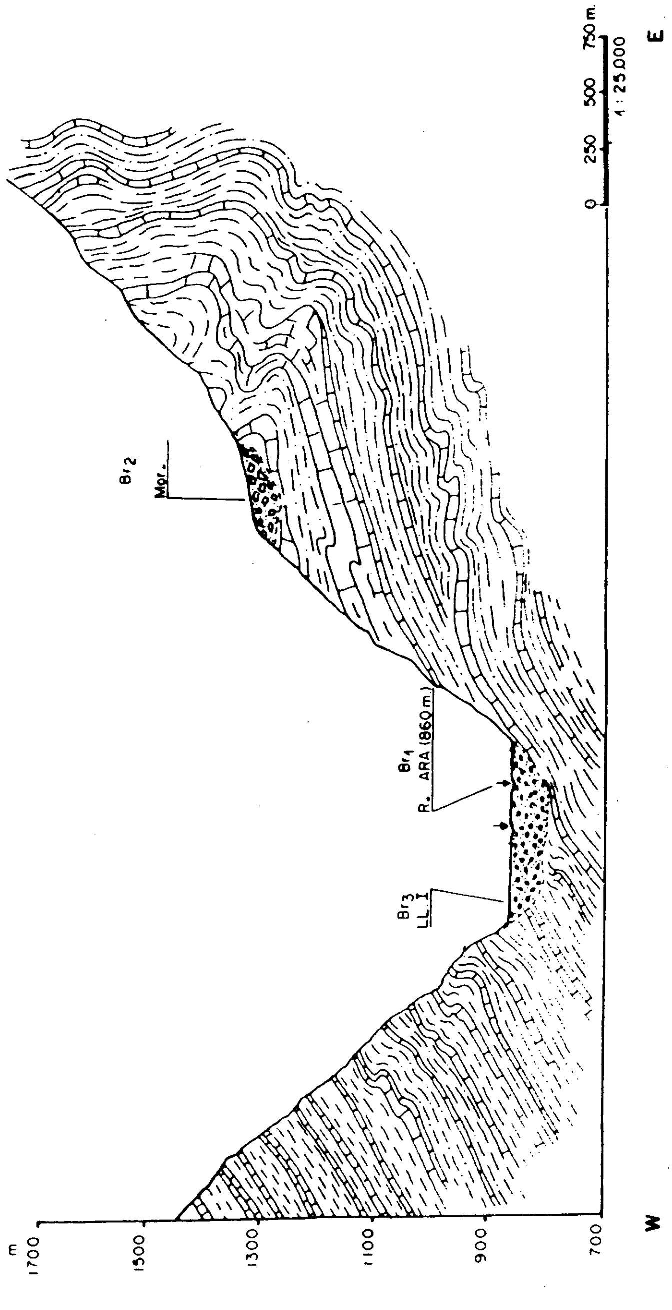

Figure 2. Localization of samples from Broto.
Localización de las muestras tomadas en Broto.

and from where most of the samples were collected, F1 (fan of the right hand bank at 50-60 m), F2 (terrace on the right hand bank at 35-40 m), F3 (present sand bar), F4 (terrace on the left hand bank at 8-12 m) and F5 (coluvion of the left hand bank). The main characteristics of this contour of Fiscal is the existence of ravines on its left hand bank: here are located the most ancient fans found in the river Ara at 130-140m.

The other three samples are characteristic of the contour of Ligüerre de Ara, L1 (present sand bar), L2 (flood plains) and L3 (terrace on the left hand bank at 8-12 m).

At Planillo, the valley is still very wide, with a system of interweaved channels and very important ravines with fans, one of them, located on the left hand bank is a glacis cone at 84 m (P4), the other samples from this contour are P1 (present sand bar), P3 (cone at 8-12 m), P5 (cone at 55-60 m), P6 (terrace on the right hand bank at 8-12 m) and P8 (terrace on the right hand bank at 55-66 m).

In the study of the area of Jánovas there are three oddities, the first one is merely structural, it is a serious tectonic accident where the anticline of Boltaña is located transversely to the valley of river Ara, which crosses it through an spectacular gorge. The second one, is the existence of a level of fluvial accumulation at 54 m above the river, which is the same height of the oldest terrace found at Aínsa; and the third one, the characterization of a scree (grèzes litées). From this contour the following samples were taken, J1 (terrace on the left hand bank at 58-64 m), J2 (the same previous terrace in the right hand bank), J3 (terrace which is similar to J1 but with a red soil), J4 (terrace on the left hand bank at 40 m), J5 (present sand bar) and J6 (grèzes litées) (Figure 3).

After the narrow stretch of Jánovas, the valley increases its width remarkably at Boltaña, whose contour is represented by samples B1 (terrace on the left hand bank at 65-72 m), B2 (present sand bar), B3 (high terrace on the left hand bank belonging to red soil), B4 (terrace on the right hand bank at 60 m and red soil), B5 (terrace at 60 m of the right hand bank), B6 (terrace on the right hand bank at 8-12 m), B7 (glacis) and B8 (flood plain). In this area the main sources of sediments are coluvions, generally unstable, and some ravine streams running from the flysch Eocene.

As the valley enters the marls of the Middle Depression, it widens itself continuously and the river Ara shows the most complete series of terrace levels of the whole valley. At Aínsa the contour includes the following samples A1 (terrace on the left hand bank at 4-6 m), A2 (terrace on the right hand bank at 55-65 m), A3 (same terrace on the left hand bank), A4 (cone at 10 m), A5 (terrace on the left hand bank at 15-18 m), A6 (present sand bar), A7 (terrace on the left hand bank with read soil at 35-65 m), A8 (terrace on the right hand bank at 8-12 m), A9 (flood plain), A10 (terrace on the right hand bank

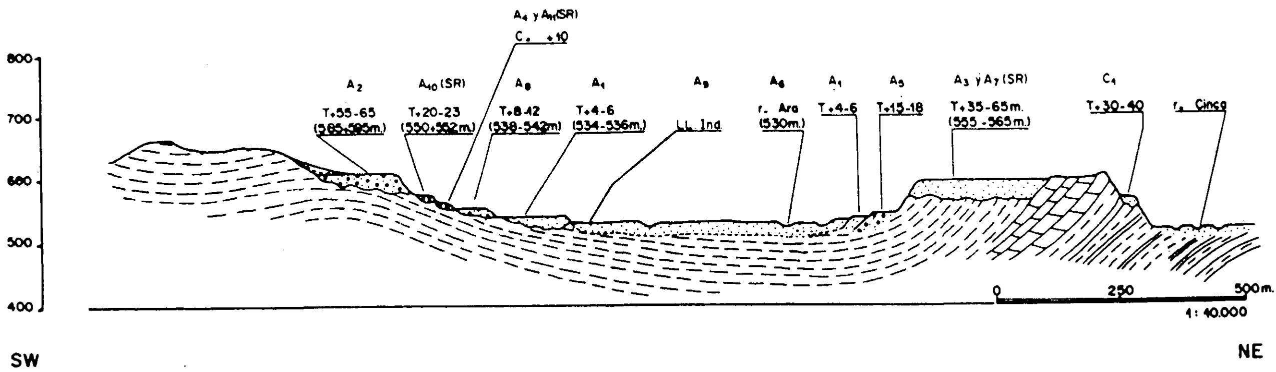

Figure 3. Localization of samples from Aínsa.
Localización de las muestras tomadas en Aínsa.

with red soil at 20-23 m) and A11 (cone with red soil at 10 m). The only sample from the valley of the Cinca river, was collected to correlate the evolution of both valleys (C).

Identical analysis, both physical and chemical, has been performed on all the samples, a total of 44, in order to establish their pH, conductivity, organic matter content, carbonates and concentration of iron and manganese oxides (crystallized and amorphous), besides the determination of the grain size distribution measuring the proportions of sand, silt and clay, according to Soil Conservation Service (1972).

Specific analysis were performed on certain fractions; thus, on the sand fraction the mineralogy was studied by separation with bromoform and counting of mineral grains with petrographic microscope; on the clay fraction an analysis was made of its minerals by X-Ray diffraction, preparing oriented air dried aggregates, glycollated with ethylene-glycol, according to BRUNTON (1955) and calcinated at 550 °C, measuring the samples according to the reflectant powers recommended by BARAHONA (1974) and VAN DER MAREL (1966). Besides theses X-Ray Diffraction Analysis mineralogic study of the total sample was performed, with quartz, potasic feldspath, calcisodium feldspath, phyllosillicates, calcite, dolomite, kaolinite, illite, smectite, clorite and sepiolite.

To complete the set of analysis it was performed a chemical humid process analysis on major, Fe_2O_3, Al_2O_3, CaO, MgO, K_2O, Na_2O, MnO, TiO_2 and SiO_2, and minor elements, Pb, Cr, Zn, Cu, Ni, Zr, by means of a triacid attack and determination of all the elements through atomic absorption spectrometry.

The results are shown in Table 1.

4. Results and discussion

Due to the high number of samples, 44, and variables, 34, the statistics computer program BMDP 4M (1983) was used to be able to manage the results. The first step was to obtain the correlation matrix for the various variables and the significance levels. The interpretation of the results seems to show that carbonates appear correlated with sand, thus, in the area under study, carbonate is associated with the coarse textural fraction, while clay is linked to quartz, which proves its relationship with finer fractions. On the other hand, silt is associated with forms of iron oxide with less degree of crystallinity.

It is important to take into account the high correlations existing between a group of trace elements such as chrome, lead, zinc and nickel, with the various forms of manganese oxides, independently of their crystallinity.

SAMPLE	CLAY (%)	Fe am (X0.01%)	Mn am (X0.01%)	Fe gl (0.1%)	Mn gl (0.1%)	Ca-Do (%)	Q (%)	FK (%)	Phyl (%)	Illi (%)	Smec (%)	Sep (%)	CaO (%)	MgO (%)	Al_2O_3 (%)	SiO_2 (%)	Pb (ppm)	Cu (ppm)	Zn (ppm)	Cr (ppm)	Ni (ppm)
A3	1	6	<0.00	70	<0.00	68	22	<1	10	27	14	<1	9.40	0.43	17.27	58.34	<5	12	130	<1	<5
A7	13	8	3.61	14	0.39	10	58	<1	32	92	5	<1	0.30	0.59	18.14	56.53	10	12	480	8	<5
A5	5	11	<0.00	94	<0.00	59	17	4	12	84	5	<1	9.32	0.59	16.71	54.82	<5	19	172	<1	<5
A1	40	14	1.29	44	1.29	77	15	1	7	78	5	<1	9.37	0.66	17.19	55.06	<5	11	176	<1	<5
A9	28	35	0.51	3	0.64	50	27	2	15	84	9	<1	8.90	0.85	15.33	61.71	6	14	307	9	5
A6	12	7	0.90	14	2.20	52	17	6	15	79	10	3	10.15	0.53	17.53	52.52	<5	16	208	6	<5
A8	26	11	0.91	7	0.63	55	18	5	12	79	13	<1	9.22	0.73	17.53	53.58	8	10	315	8	5
A10	33	20	4.26	22	0.88	10	30	9	48	73	17	5	2.15	1.35	16.22	57.03	<5	15	513	9	5
A2	18	10	<0.00	43	<0.00	4	23	2	22	53	15	<1	7.50	0.49	16.10	57.27	<5	18	183	<1	<5
A4	10	13	<0.00	106	<0.00	64	14	<1	22	87	6	<1	9.45	0.68	15.62	63.14	<5	18	161	<1	<5
A11	26	13	2.74	24	0.63	24	40	<1	36	85	5	<1	5.46	0.87	17.14	64.30	8	16	442	9	5
B7	3	6	<0.00	7	<0.00	60	10	<1	8	82	3	<1	9.49	0.37	16.49	53.26	<5	19	148	<1	<5
B5	5	11	<0.00	117	<0.00	69	12	6	13	89	1	<1	9.43	0.35	15.95	48.61	<5	11	198	<1	<5
B4	16	20	<0.00	181	<0.00	12	54	3	23	44	14	38	0.65	0.07	16.32	63.70	<5	9	162	<1	<5
B6	5	11	<0.00	74	<0.00	67	13	2	14	70	14	16	9.41	0.58	16.93	53.26	<5	19	155	<1	<5
B8	16	6	0.64	5	0.39	57	36	<1	6	76	18	4	9.50	0.63	16.51	53.65	10	9	166	8	<5
B2	2	3	<0.00	34	0.25	77	10	1	6	72	4	<1	9.49	0.67	16.46	55.70	<5	13	134	<1	<5
B1	9	6	<0.00	53	<0.00	72	14	6	8	94	<1	<1	9.38	0.44	16.83	54.83	<5	10	153	<1	<5
B3	31	9	0.25	43	0.50	28	18	2	25	70	15	<1	6.83	0.47	16.30	58.06	<5	10	169	<1	<5
J1	18	17	<0.00	33	<0.00	27	61	<1	6	86	2	<1	1.23	0.43	15.81	69.82	<5	23	170	<1	<5
J4	23	13	1.29	39	1.29	13	11	24	48	47	17	3	62.8	0.55	15.90	57.35	<5	7	197	<1	<5
J6	28	7	0.58	14	0.32	51	10	<1	29	66	19	5	8.98	1.02	15.22	60.59	5	50	341	8	5
J5	17	4	0.26	4	0.12	62	13	5	13	78	15	21	0.57	0.48	16.58	56.73	8	13	347	8	<5
J2	43	13	<0.00	37	<0.00	<1	62	<1	28	79	2	<1	0.78	0.37	16.40	62.96	<5	19	162	<1	<5
J3	28	19	1.29	178	<0.00	1	43	2	40	47	15	<1	1.71	0.34	16.09	63.57	<5	16	169	<1	<5
P4	24	3	1.29	19	2.45	40	30	<1	22	82	10	<1	8.86	0.29	17.72	52.64	10	21	322	12	6
P3	28	34	7.60	29	3.00	6	48	<1	29	88	2	<1	1.19	2.45	17.68	54.93	7	19	594	12	6
P1	17	7	0.52	16	1.29	53	31	<1	10	77	8	<1	10.15	0.23	16.48	53.83	10	15	317	9	5
P6	26	27	9.99	40	2.71	9	43	<1	40	57	15	<1	0.45	2.51	16.34	60.03	7	21	485	13	6
P5	29	10	4.00	35	3.00	<1	73	<1	27	90	3	<1	0.23	2.06	16.50	57.64	6	22	600	13	7
P8	40	21	4.25	31	2.80	2	58	<1	35	86	5	<1	0.17	2.98	16.64	58.21	14	28	688	16	7
P10	44	13	9.99	15	0.26	41	26	<1	18	76	15	5	3.42	0.89	16.30	62.62	12	21	416	15	7
L1	14	12	0.30	5	0.30	32	24	<1	32	79	5	<1	5.39	0.70	15.51	65.51	9	16	328	10	6
L2	10	3	0.52	12	1.29	51	16	<1	27	73	3	<1	9.17	0.75	15.26	60.15	8	13	167	9	5
L3	22	13	1.51	14	0.62	9	38	<1	36	61	18	<1	1.08	1.33	15.74	63.22	10	18	273	12	6
F1	25	5	3.00	11	0.65	42	15	<1	27	76	16	<1	10.77	0.40	19.51	53.24	8	21	271	15	7
F2	23	8	3.12	13	0.52	15	35	<1	38	75	12	<1	3.96	0.38	18.25	57.14	9	24	630	25	8
F3	10	7	0.65	4	0.13	54	20	<1	18	70	8	<1	11.51	0.98	18.30	53.85	9	16	305	12	6
F4	21	11	3.00	9	0.78	29	37	<1	23	73	12	<1	4.72	0.52	17.26	60.65	9	24	451	16	7
F5	20	7	1.16	7	0.35	60	11	<1	19	81	11	<1	12.64	0.31	16.18	56.01	8	21	356	15	7
Br1	14	9	0.65	4	0.12	40	12	14	26	86	8	<1	4.97	0.84	15.10	58.17	7	9	336	5	<5
Br3	20	14	1.22	6	0.44	32	27	12	19	71	14	<1	5.00	0.96	15.30	59.80	<5	10	397	8	5
Br2	18	8	1.29	6	0.26	45	10	10	30	88	10	<1	3.83	1.52	15.17	62.66	<5	13	528	8	<5
C1	15	14	<0.00	163	<0.00	5	26	14	43	69	4	13	1.63	0.43	17.06	57.38	<5	21	176	<1	<5

Table 1.- Physical-chemical characterization of sediments according to clay, contents of amorphous iron oxides, amorphous manganese oxides, glassy iron, glassy manganese, calcite and dolomite, quartz, potasic, feldspath, phyllosillicate, kaolinite, illite, smectite, sepiolite, and chemical composition.

Caracterización fisico-química de los sedimentos según arcilla, contenido en óxido de hierro amorfo, en óxido de manganeso amorfo, hierro cristalino, manganeso cristalino, calcita y dolomita, cuazo, potasio, feldespato, filosilicatos, kaolinita, ilita, esmectita, sepiolita y composición química.

Phyllosilicate appears to be correlated, at maximum level of significance, with magnesium and as this element has a negative correlation with carbonates, it suggests that the magnesium in this area is mainly composed of crystalline nets of silicates, besides retaining in its structures copper and zinc to which it is linked.

From the application of the statistics program we obtained eleven charge factorswere obtained, explaining 84% of the total variance. Only the first five are commented (Table 4).

Factor 1 explains the maximum percentage of variance between all the factors that were obtained (29.65% of the total variance); it is represented by chrome, lead, nickel and zinc; in this factor the best crystallized iron oxides appear with negative charges, while less crystalline manganese oxides appear with positive charges. So this factor might be consi-dered as represented by the above mentioned microelements associated to amorphous manganese oxides.

Factor 2 explains a 17.6% of the total variance. It is represented by carbonates.

Factor 3 explains a 9.8% of the total variance. It shows the greatest charges for aluminum, silicon and illite and can be considered as an indicative factor for granite lithologies.

Factor 4 explains 8.9% of the total variance. It is represented by magnesium, iron oxides in their least crystallized forms and all the manganese oxides. It might be interpreted as an alteration factor linked to the formation of metallic oxides.

Finally, factor 5 explains 7.3% of the total variance. Its highest charge corresponds to potassium feldspar, smectite, phyllosilicates, copper and sepiolite. It is again concerned with a manifestation of the alteration, possibly linked to the genesis of the clay minerals. The lack of illite in this factor may confirm the granite origin inherited by it and the different genesis of the set of minerals of the clay in the sediments that were studied. It seems that illite is autochthonous, while sepiolite and smectite might proceed from the alteration of feldspar, amphiboles and phyllosilicates of the original material. The presence of copper in this factor 5, corroborates again the special affinity of this metal for the association with phyllosilicates that appear in it.

The two dimension diagram of factor 1 versus factor 2 (Figure 4) allows a clear differentiation between areas. Concerning factor 1, determined by the microelements associated with the amorphous manganese oxides, axis of the abscissas, samples from Planillo and Fiscal show the largest contents, locating themselves in the positive side of this axis, while Jánovas, Boltaña and Aínsa appear mostly located in the negative side of the factor, although some of the samples from Aínsa (A5, A7, A8 and A11) and from Jánovas (J5 and J6) do not

CHARGE FACTOR 1	
components	*charge*
Cr	0.900
Pb	0.869
Ni	0.844
Fe cr	–0.726
Zn	0.623
Mn am	0.529

CHARGE FACTOR 2	
components	*charge*
Ca-Do	0.858
Q	–0.804
Fe_2O_3	–0.563
Clay	–0.520
Phyll	–0.503
Fe	–0.563

CHARGE FACTOR 3	
components	*charge*
Al_2O_3	0.933
SiO_2	0.856
Illi	0.715

CHARGE FACTOR 4	
components	*charge*
MgO	0.814
Fe am	0.623
Mn cr	0.562
Mn am	0.555

CHARGE FACTOR 5	
components	*charge*
FK	0.760
Smec	0.596
Phyll	0.577
Cu	0.559
Sepi	0.539

Table 2. Charge factors of the components.
Factores de carga de los componentes.

follow this tendency. For factor 2, which corresponds to the carbonates and located in the axis of the ordinates, it can be observed a differentiation between samples, although not as visible as for the one previously mentioned.

Samples from Aínsa are characterized by their high contents of carbonates corresponding to the present sand bars, flood plains and low height terraces, same as those from Boltaña, with the exception of B4 and B3.

Samples from Jánovas with the highest contents of iron oxides are those from the oldest terraces, while those with highest contents of carbonate belong to the present sand bars and grèzes litées. On the other hand, samples from Planillo show the highest contents of chrome, lead, nickel and zinc.

The most important characteristic of the samples from Broto and Ligüerre de Ara is their homogeneity, while those from Fiscal are divided into those with high contents of carbonate (present sand bar and sewers) and the rest, with a lower concentration of these minerals.

Figure 5 is a graphic of factors 2 and 5, the first one related to the presence of carbonates and the second, associated with the mineral alteration and the genesis of the clays minerals. From their study one can conclude that for Aínsa and Boltaña there is a great dispersion in values along the whole diagram. Between the transects of Jánovas and Planillo, very well delimited areas are deduced, being of great interest the antagonism of samples J4 and J1, with opposed values of alteration. Of the remaining samples, Ligüerre de Ara, Fiscal and Broto, the most important fact is the disposition of the sediments in Broto, that even belonging to elements which are morphologically different (morain, present sand bar and flood plain) (BENN, 1994;

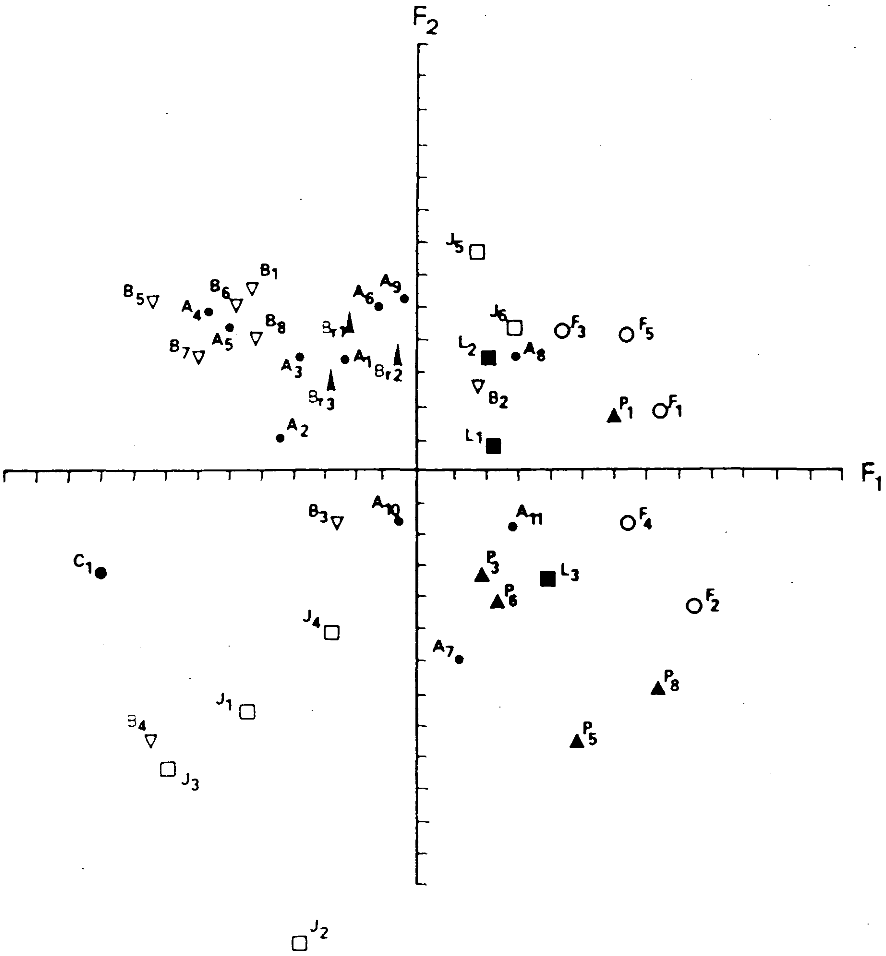

Figure 4. Graphical representation of factor 1 versus factor 2.
Representación gráfica del factor 1 frente al factor 2.

REINFELDS & NANSON, 1993) show a homogenous behavior in relation to the percentage of carbonates and the level of alteration. The high contents of potassium feldspar that might be associated to the geographic location; thus, Broto is quite close to the head of the river Ara and so, next to the granite batholiths and the only one with morainic deposits and, because of this, the contribution of granites might have greater importance, as is corroborated by the mineralogical identification of the sand fraction in which fluorite appears among the minerals.

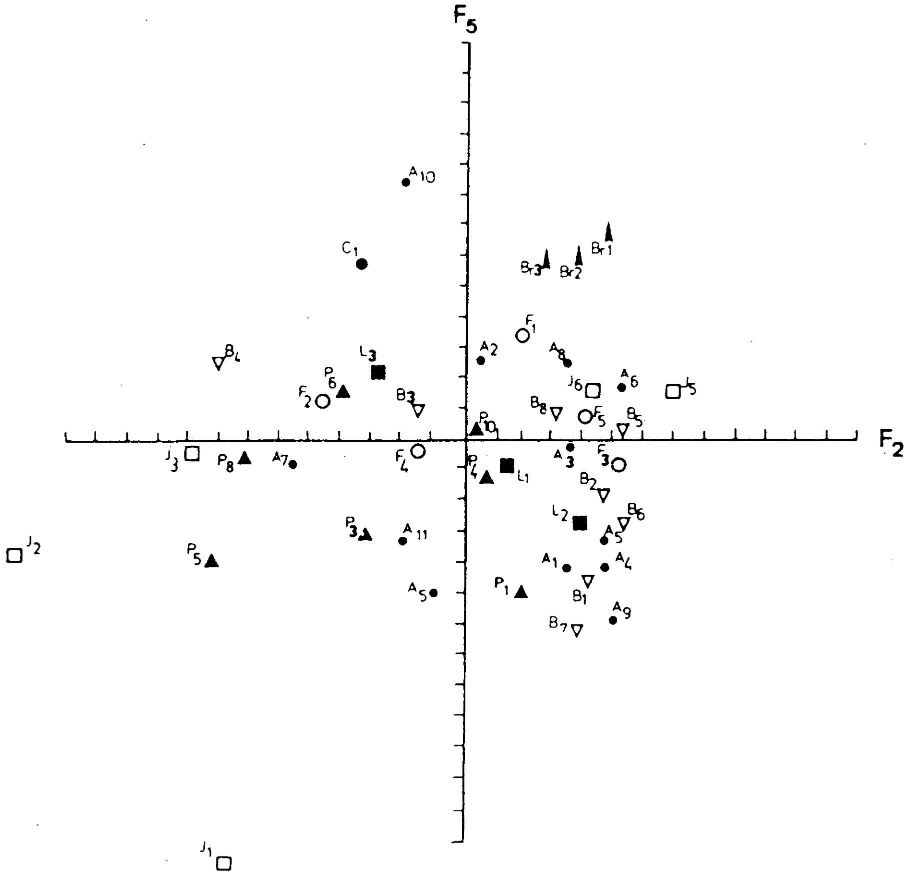

Figure 5. Graphical representation of factor 2 versus factor 5.
Representación gráfica del factor 2 frente al factor 5.

5. Conclusions

The application of mineralogic analysis, chemical and statistical methods to certain sediments of the Ara river (Central Pyrenees, Spain) allows to achieve a wider knowledge of the processes of alteration and genesis of superficial formations, which are present in the basin.

The microelements and minerals, found in the different textural fractions, are the indicators of this processes.

In the sediments studied, the carbonate is found in the thicker textural formation, without existing a progressively more evolutioned composition as older terraces are studied; a certain parallelism among the present alluvial and the highest levels is even detected. This could be due to the recycling that the alluvial sediments and the processes of sloping have always had in the basin, polluting the levels under a formation process.

On the other hand, there is a predominance of quartzes and phyllosilicates in the thinnest textural fraction and also the prevalence of this fraction over the thicker one, which reveals an stressed link with the petrographic characteristics of the bed rock which form the basin of this river.

The microelements seem to show differences in relation with their dynamics; in this way chrome, lead and nickel are associated with manganese metal oxides, independently of their crystallinity degree, whereas copper and zinc are associated with the phyllosilicates.

A sign of alteration is related, on one side, with the formation of metal oxides of iron and manganese, and on the other side, with the genesis of the neoformation clay minerals, that is, sepiolite and smectite.

In relation with the clay minerals, differences related with their origin are observed: in this way, the illite seems to have a granitic origin associated with a character inherited or linked with the morainic deposits existent in the basin. The sepiolite and smectite could come from the alteration of feldspars, anphybols and phyllosilicates, as corresponds with a basin worked essentially in formations of the flysch, revealing the influence of the colluvial process during the Quaternary.

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