ORIGIN OF THE STEPHANIAN RED BEDS IN THE OCEJO BASIN (PROV. OF LEON, SPAIN).

BY

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ABSTRACT

In the valley of Ocejo (prov. León) a series of alternating conglomerates, sandstones, siltstones, and shales with a red colour are found. This series is 180 m thick, of Stephanian B + C age, and at present dips ± 30°W.

Sedimentological analysis gives the following data: (1) quartz is the dominant detrital mineral, hematite and clay form the cement; (2) the components of the conglomerates are chiefly limestones of cobble size, the fine-grained sediments and matrices being chiefly siltstones with varying admixtures of clay size material; (3) the limestone pebbles have low roundness- and flatness-index values.

The sediment was deposited by torrents at the foot of a rising mountain area. The source region had a thick cover of red soil on top of limestones. Rapid erosion in these elements caused the deposition of limestone conglomerates in a red matrix during a period in which the climate was warm and humid.

RESUMEN

En el valle de Ocejo (prov. de León) aflora una serie con una alternación de conglomerados, areniscas, limos (cementados) y esquistos arcillosos de color rojo. Esta serie tiene un espesor de 180 m, una edad Estefanense B + C, y una inclinación de ± 30°W.

Los analisis sedimentológicos proveen los datos siguientes: (1) el cuarzo es el mineral detritico dominante, la hematita y la arcilla componen el cemento; (2) las capas gravosas son en su mayoría conglomerados calcareos cantosos, y los sedimentos mas finos y las matrices son en su mayoría limos cementados con diferentes cantidades de la fracción arcilla; (3) los cantos de caliza son poco desgastados y aplanados.

El sedimento fué depositado al pie de una zona montañosa en elevación mediante torrentes. Esta región montañosa fué cubierta de suelos rojos yacentes sobre calizas. Una erosión rápida en estos originó la deposición de conglomerados calcáreos con una matriz roja. El clima fué cálido y húmedo.

INTRODUCTION

Along the southern border of the Cantabrian Mountains a number of basins filled up with Stephanian deposits are found. In one of these, the basin of Ocejo in the N part of the province of León (Fig. 1), a series of red sediments consisting of conglomerates, sandstones, siltstones and shales rests unconformably on top of the Visean. The authors' attention was drawn to this local deposit by the assistants of Prof. de Sitter, who is mapping the geology of this area with his students. An investigation into the origin and source of these sediments was started in the summer of 1961, when the section presented in Fig. 2 was measured. The samples were later analysed in the laboratory as to mineralogical composition, grain size and morphometry of the pebbles. The age of the sediments as determined by Wagner (1959) is considered to be Stephanian B + C.

The section shows an initial conglomerate of quartzite pebbles, on which rests a breccia of limestone fragments. The following layers are composed of alternating limestone conglomerates, sandstones and siltstones, and shales, all with a red colour.

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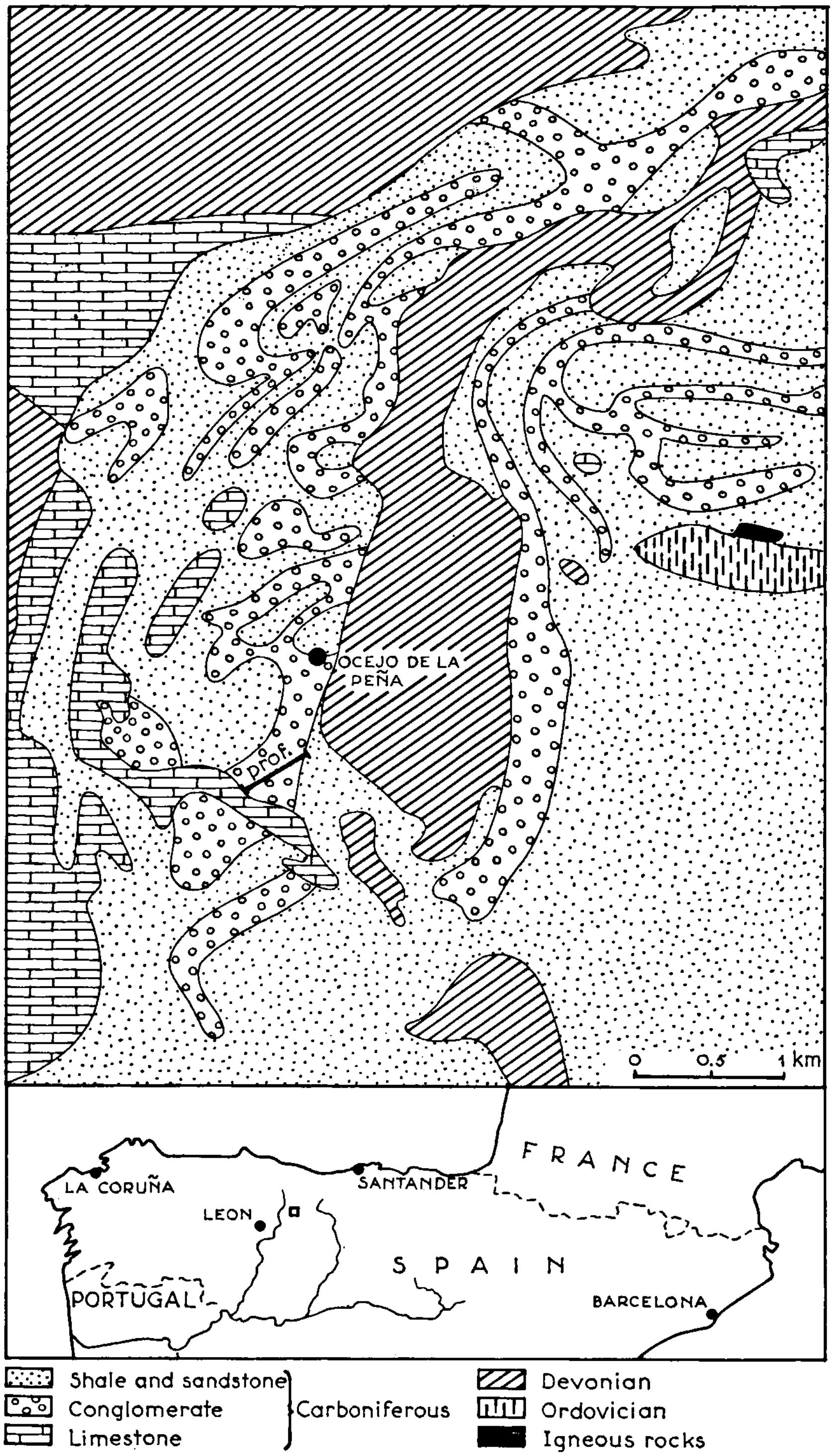

Fig. 1. Situation of the investigated section and its geological setting. (drawn after De Sitter 1961).

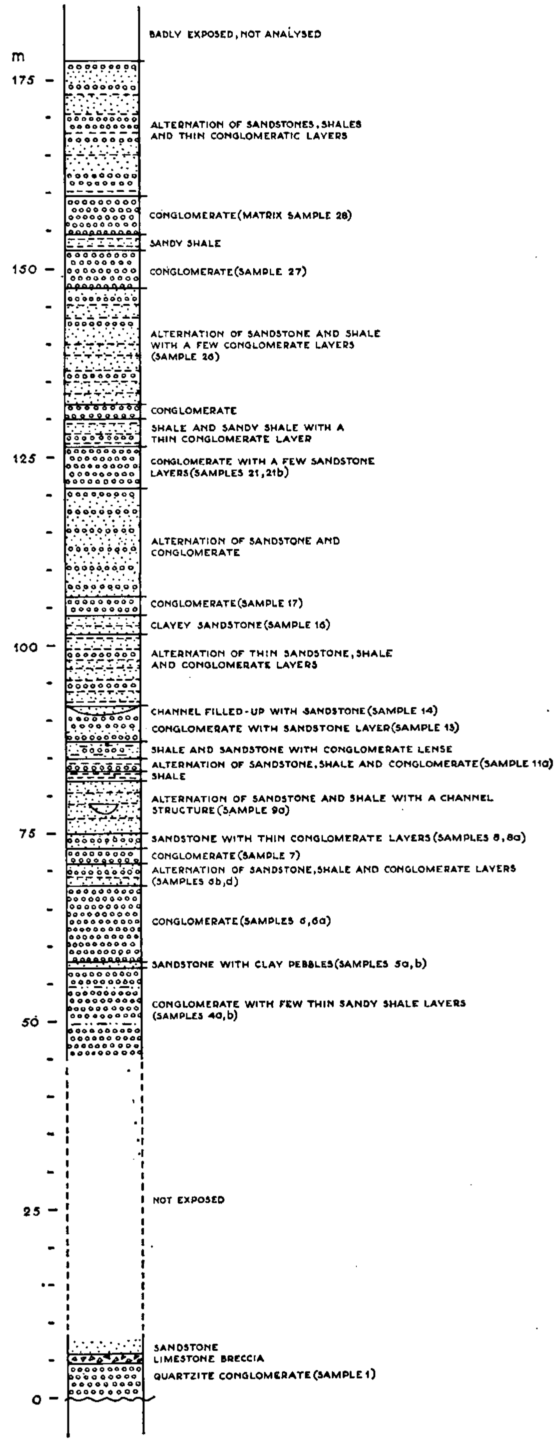

Fig. 2. Section through the measured sequence.

RESULTS OF THE ANALYSES

MINERALOGY

The mineralogical composition of the various sandstones and matrices does not differ essentially. Table 1 gives the data obtained from samples of which a thin-section could be made. It is evident that the differences concern only the relative proportions of a small number of minerals.

In all the samples, quartz is the dominant detrital component; in a number of them, the quartz is even the dominant mineral. In the majority of the deposits, however, the cement dominates. This may then be hematitic (samples 4a and 21b, possibly iron sandstones), clayey (samples 6a, 8, 6b), or both (sample 4b).

The quartz grains are not turbid. Generally they contain no inclusions apart from a few idiomorphic grains of zircon and sometimes rutile which may give the quartz a somewhat cloudy appearance.

Only a few quartz grains are composite. The mineral shows an undulating extinction; the grains are sub-angular to sub-rounded. Some of them show pitting, the pits being filled up by the clayey matrix. Often their edges are worn and their form suggests a solution after the final settling. This suggestion is confirmed by the following observations. Around the clastic grains a dark rim of ferric material can often be observed. The quartz inside these rims also shows solution features. Secondary overgrowths are rarely found, even in the samples poor in clay.

Other detrital constituents are present only in minor amounts. Feldspars were not observed at all; a few non-elongated flakes of muscovite and biotite are seen. Glauconite is also present as rounded grains; hence, it must be considered as detrital in origin. Among the rock-fragments are chert grains and shale fragments. The heavy minerals are represented by rounded, bluish tourmaline and slightly rounded zircon. Some organic remains do occur; these are also detrital, but their material has been replaced by hematite and sometimes even by glauconite.

Dr. P. Hartman, who kindly interpreted the X-ray photographs of the clay fraction, found that, although its bulk consists of illite, kaolinite is present in amounts of up to 20—25 %. Further he reports one mineral of the chlorite group and possibly some vermiculite.

The colour of the sediment is rather characteristic, because the series is a red bed sequence. In thin sections patches of green colour can be observed, which are caused by the presence of clay, the red colour being due to hematite. Because the clay is chiefly illitic, the green tint may be caused by ferrous iron, built into the illite lattice (Rasumova 1960).

The first point to attract attention is the absence of feldspars and micas among the detrital constituents. The presence of sandstone and limestone pebbles indicate the occurrence of sedimentary rocks in the source area. These older sediments are already mature and are poor in feldspars and micas, so their absence in the younger sediment is easily explained by the polycyclic origin of the sedimentary material. The rounded blue tourmaline points to the same conclusion (Krynine 1946). The high percentage of angular grains does not exclude a polycyclic origin, since we know, firstly, that sandstones and sandy limestones were present in the source area (also as pebbles) in which the quartzes have irregular outlines, and secondly, that the roundness is the result of solution as explained by Kuenen & Perdok (1960).

As stated above solution of quartz took place after deposition of the grains. This implies that the enviromnent was alkaline (Krauskop 1959). The possible presence of a chlorite in the clay mineral association also confirms this supposition.

If such were the case, the kaolinite formation would then antedate the sedimentary environment, and have been already formed in the acid environment of the soils in the source area (Carroll 1959). Illite came directly from the freshly-weathered bed-rock. A possible presence of some vermiculite may be caused by alteration of biotites, either in the source area or in the area of deposition.

Hematite must have been derived from the source area. It forms the principal pigment and is finely diffused, permeating the entire rock mass. This is a common feature in red beds (Van Houten 1961).

The nearly total absence of carbonates, either as cement or as (primary) detrital fragments is striking. This is the more conspicuous because the majority of the pebbles of the conglomerates are limestone pebbles. Possibly the pebbles due to their size are the only fragments that could survive the strong solution of the carbonates in the source area.

GRAIN SIZE

Size determination of the conglomerates was done according to Hörner (1944). The finer fractions and the deposits without pebbles were analysed in the laboratory, as far as possible with the usual methods (Mabesoone 1959). Finally, some of the coarse sandstones were analysed as to their size distribution in thin-sections by the ribbon-counting method recently introduced by Van der Plas (1962). The results, with exception of those for the thin-sections, are presented as cumulative curves in Fig. 3 for some conglomerates and in Fig. 4 for some of the finer grained sediments.

The conglomerates have their maximum size class in the fraction 20-2 cm (cobbles and coarse pebbles), and are fairly well sorted (So = $\pm$ 3). Only sample 1,

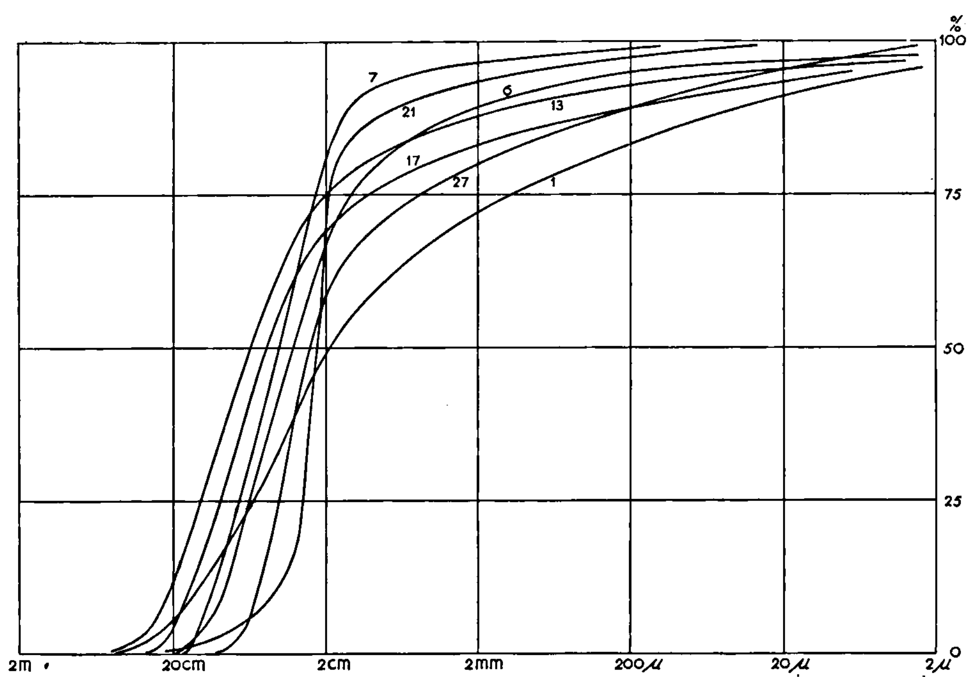

Fig. 3. Cumulative curves of the granulometric composition of some conglomerates.

the lowermost conglomerate on top of the underlying Visean limestones, is less well sorted (So = 8), but the bed stands apart for the smaller size of the pebbles, being medium to fine, and for the different composition of the pebbles. These data point to either fluvial sediments or sub-humid mountain-foot fans.

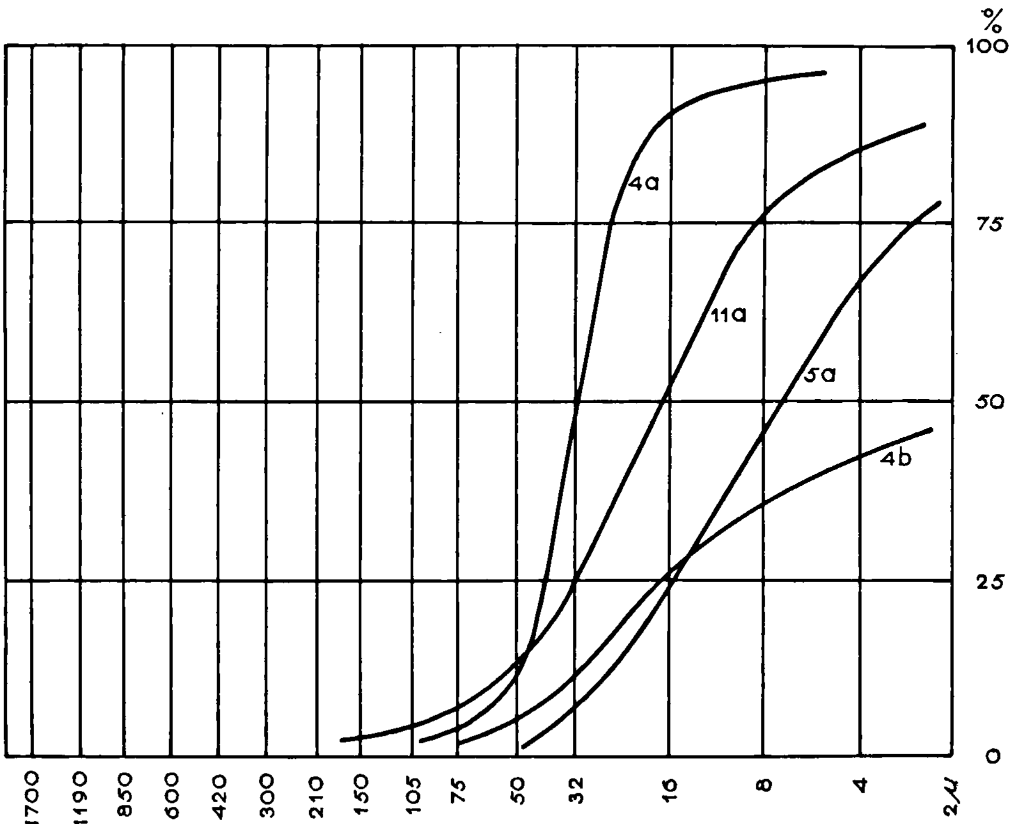

Fig. 4. Cumulative curves of the grain size composition of the finer deposits.

The cumulative curves of the finer deposits fall into three groups, one sample of each being presented in the diagram (4a, 5a, and 4b). The relevant data for all analysed samples are given in Table 2. Sample 4a is a sediment, called in the field "sandstone", sample 5a is a matrix of a conglomerate, and sample 4b a shaly matrix. Sample 11a is certainly a "sandstone" with admixture of finer particles; it is the only sample which shows this type of curve, and therefore it does not represent a member of a special group. The most obvious feature is that the modes of the so-called sandstones lie in the coarse silt size fractions (50-16μ), and those of the so-called coarse matrices in the fine silt size (16-2μ). These deposits must therefore be called siltstones. This is also easily seen from the location of the samples in a sand-silt-clay triangle-diagram (Fig. 5). Only the three finer deposits contain more clayey components. The other deposits are found in an angle of the diagram in which usually only loess deposits can be found. The samples analysed in thin-sections are real sandstones, having the bulk of the grains in the 300-75μ fractions, and containing a fairly high admixture of clay. These sediments could not be analysed in the laboratory because their cement was not soluble in acid.

In the sense of Doeglas (1946) the sediment sequence 4a-11a-5a-4b point to S-fractions with an increasing content of T-material. Such sediments are indicative for environments with low current velocities, from time to time decreasing to zero. This suggests deposits of rivers, which sometimes stagnated soas to become lakes or ponds. The sorting values, given in Table 2, however, are low, which means a fairly well sorted sediment. The sandstones with their high clay content may be fluvial sediments. In our opinion, eolian influence, if it was ever present, could never have been of importance.

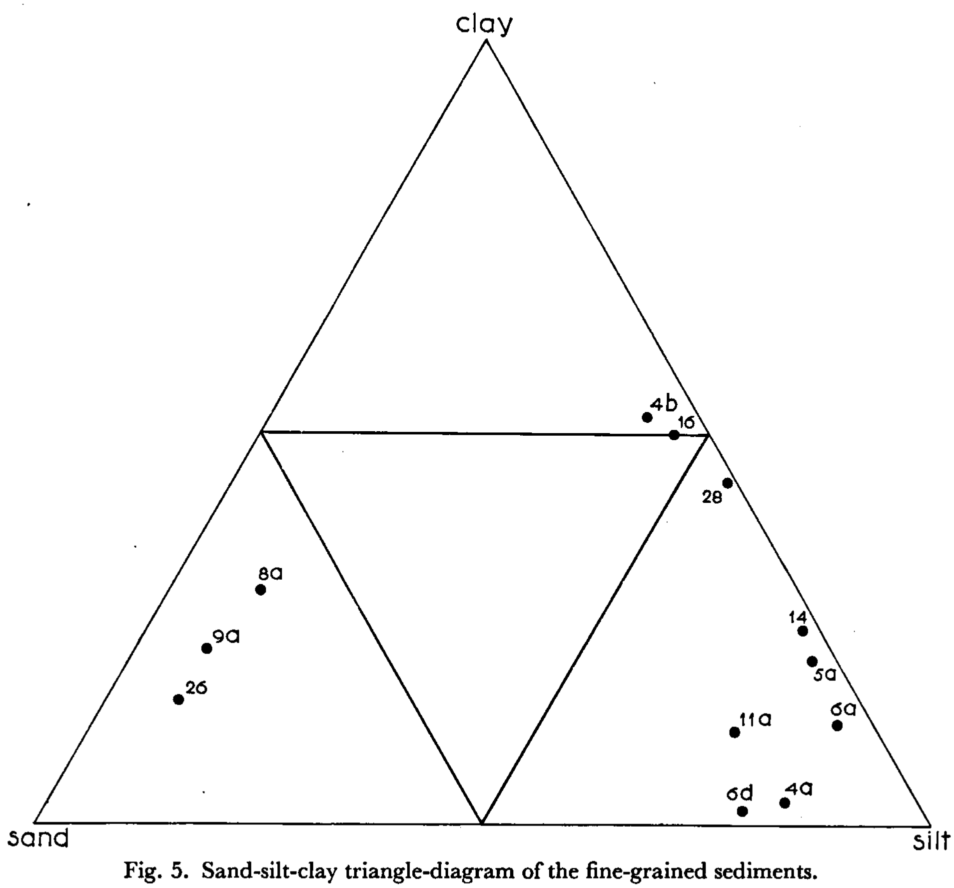

Fig. 5. Sand-silt-clay triangle-diagram of the fine-grained sediments.

PEBBLES

The lower conglomeratic layer, situated directly on top of the Visean deposits, consists chiefly of quartzites (82 %) with admixtures of limestones (9 %) and quartz (9 %). The quartzites are fairly well-rounded, but it was not possible to obtain enough pebbles for a morphometrical analysis. The limestones, however, are angular.

All other conglomerates consist for the major part of limestone pebbles (85-90%).

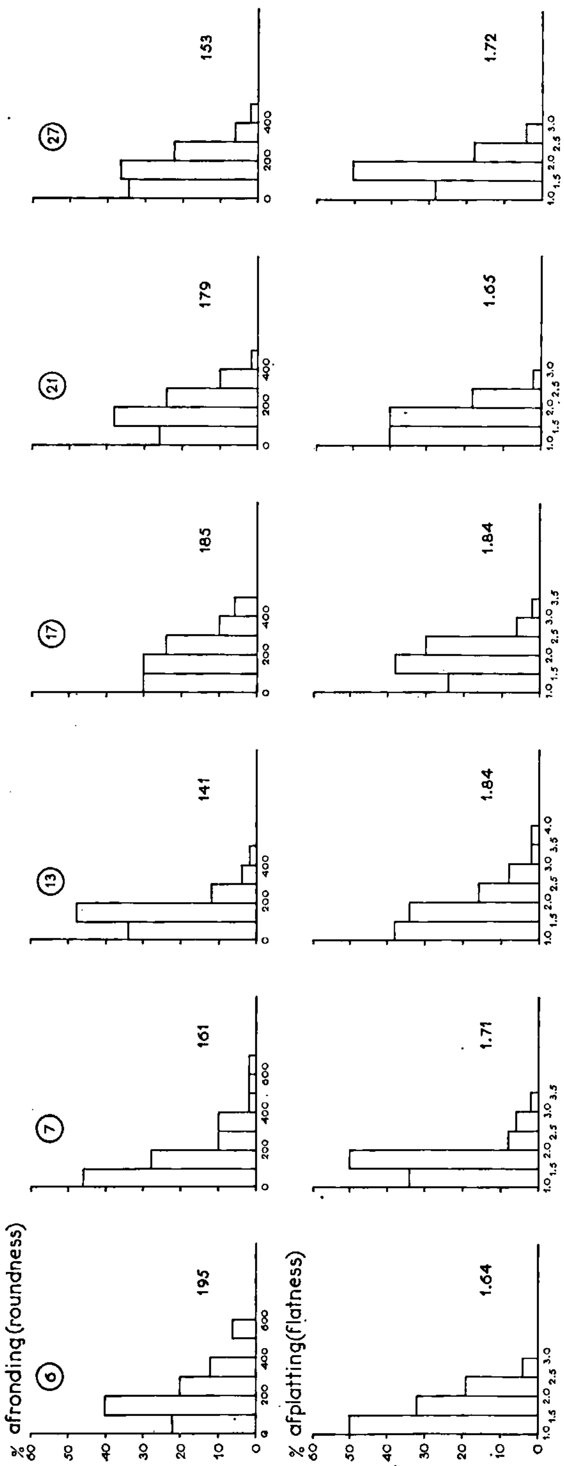

Fig. 6. Histograms of limestone pebble roundness and flatness of some conglomerates.

The admixtures in them are quartzites and sandstones. The roundness and flatness of the limestone pebbles were determined after the method of Cailleux (Cailleux & Tricart 1959); the results are given in Fig. 6. It may be concluded that the pebbles are only angular to sub-rounded and that they are not flattened. This means that these pebbles were transported over only a short distance, because limestones are very susceptible to rounding and solution processes. Furthermore low roundness-indices in combination with low flatness-indices, may point to either mountain-foot debris or to fluvial shaping in a fairly arid or periglacial climate (Mabesoone 1959). In the case of this area, it is almost certain that the coarse sediment presents a mountain-foot deposit, supplied by rivers. The climate could then have been fairly humid.

CONCLUSIONS

The interpretations have already been given in the foregoing paragraphs of each of the analysis. Taking these data as a whole we may draw the following conclusions with respect to the origin of the conglomeratic series and the petrographical situation in its source area.

In the time before the deposition this source area must have had a thick cover of red soil. This may be concluded from the presence of a high quantity of kaolinite in the foreland sediment, the high hematite content which gave rise to the red colour, and the clayey and silty nature of the matrices of the conglomerates. In these soils only quartz grains survived and possibly quartzite pebbles. A thick limestone series of Visean age was covered by tropical red soils which may have developed during the Westphalian. In a following tectonic phase,possibly the Asturian phase at the beginning of the Stephanian (de Sitter 1961), an uplift of this source area took place, resulting at first in erosion of the red soils containing the quartzite pebbles, now found at the base of the complex in the Ocejo valley (sample 1). But the relief of the source area rapidly became higher, so that vertical erosion could attack the underlying limestones. Initially only small angular limestone fragments came down, resulting in the brecciated layer found on top of the quartzite conglomerate. These limestone rubbles possibly represent the partly-weathered parent material under the soils. But very soon pebbles were formed from the unaltered parent rock. Mountain torrents transported these pebbles mixed, with ancient red soil material, into the basin at the foot of the rising area. Similar features are described by Van Houten (1961).

The area of deposition was continental as indicated by the nature of the sediment and the type of the plant growth. Remains of the latter are now found in the form of coal lenses whose fossils were determined by Wagner (1959) and dated as Stephanian B + C. The bed-load of the mountain torrents was deposited in this area. Sedimentation was rapid, so that the plant remains were preserved and covered rather than oxidized. The area of deposition already had some relief, as confirmed by the fact that in an outcrop in the valley an old fan of Visean material is directly covered by the conglomerate (de Sitter & Zwart 1958). Mountain-foot fans were thus formed, but perhaps not on a very steep old relief. The material filling the pores between the pebbles was clayey as well as sandy, which means that from time to time the current velocities decreased to zero and ponds or marshes were formed. In such an area plants could grow up, and sieve out more silty and clayey components from the passing suspension. The climate was warm at that time, which is also confirmed by the presence of abundant hematite (Van Houten 1961). Furthermore the dry seasons were short and only moderately dry. Such dry periods were long enough, however, to permit desiccation of clay layers. During later erosion by a current clay pebbles could be formed which are now found in the fine-grained layers of the series. The preservation of the red detritus must also be a result of local oxidizing conditions. Eolian action may certainly be excluded. The high silt content of the majority of the fine-grained sediments can only be attributed to supply from the source area and to later diagenetic growing together of smaller clay-size particles.

The environment in the area of deposition was also slightly alkaline. This is not inferred only from the fact that the water which came from the source area must have passed through limestones, the visible features as solution of quartz, precipitation of hematite, and the presence of chlorite also point in the same direction. But it remains striking that no carbonate matter precipitated.

Later diagenetical changes caused further movement and possibly further precipitation of hematite in the sediment. The quartz grains were replaced by the clayey and hematitic cement, so as to result in pitting and worn edges.

Finally tectonic movements brought the whole sequence into its present position.

TABLE 1. Mineralogical composition of some analysed samples. (The percentages given are volume-percentages).

sample	quartz	clay + silt	opaque [1])	rock fragm.	carbonate	other const.
matrices:	%	%	%	%	%	%
4a	37.6	1.6	58.0	2.8	—	—
4b	32.8	39.6	27.6	—	—	—
6a	46.4	46.8	3.2	—	3.2	0.4
8	36.8	58.8	4.0	—	—	0.4
sandstones and siltstones:						
5b	48.4	15.2	34.0	2.4	—	—
6b	39.6	58.0	1.2	1.2	—	—
8a	55.2	37.2	5.6	.0	—	—
9a	63.2	30.0	6.8	—	—	—
21b	26.9	20.8	40.0	—	7.6	—
26	56.6	25.0	18.0	1.0	—	—

[1]) opaques being hematite and limonite, but hematite predominating.

TABLE 2. Statistical values and other data on grain-size composition of the fine-grained sediments.

	Md	So	1010gSK	q
6d	37 u	1.40	— 0.08	—
4a	32	1.28	— 0.01	—
11a	20	1.79	— 0.10	33.33
6a	11	2.35	— 0.14	26.87
5a	7	2.13	— 0.01	30.67
14	8	2.92	— 0,28	36.62
4b	2	—	—	71.62
16	2	—	—	68.49
28	4½	—	—	57.89

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