

THE CAVES OF CUNDAY (COLOMBIA, SOUTH AMERICA)

by

T. H. VAN DER HAMMEN and H. W. NELSON

(*Instituto Geologico Nacional, Bogotá, Colombia, S. A.*)

A. Geological part (Th. v. d. H.)

1. Introduction

A short time ago rumors reached Bogotá that a big cavesystem had been discovered by some farmers in the southwest of the department of Tolima, between the villages of Cunday and Purificación. This region belongs morphologically and geologically to the Eastern Cordillera, and forms the westernmost spurs of this mountain chain. As the existence of these caves was completely unknown up to that time, and as no limestones were known from that region, a scientific expedition was organized for a first exploration. The geological party of this expedition was formed by Dr. J. A. BUENO, the author and his wife. We went by car from Bogotá to Girardot and from there to Cunday. The next day we had a whole day's walk to the entrance of the caves. After two days and two nights passed underground, we left the caves some kilometers to the southwest, at the other side of the mountains. From there we had a two-days walk to the nearest-by village on the Magdalena-river, Suarez. From there we returned to Bogotá by car.

We only could explore some kilometers of the cave-system, but the guide told us that, entering south of Cunday, one can go on to the south and leave east of Purificación, at least ten kilometers southwest of the Cunday entrance. Knowing that there are several levels, these dimensions would place the Cunday-caves among the larger ones of the world.

The caves are of a very peculiar type, which was never described before as far as we know, being one of the few caves of greater extension which are not formed in limestone or other calcareous rocks.

2. Geology of the region

In fig. 1 we give a geological map and in fig. 2 a stratigraphical column of the cave-region. The strike is more or less NNE--SSW. Especially the relatively hard Upper Guadalupe sandstone (Maestrichtian) and the Lower and Upper Gualanday conglomerates (Eocene-Oligocene) form prominent ridges, which have the above-mentioned direction.

Sediments from the Upper Guadalupe sandstone downwards are marine, and from this horizon upward mainly terrestrial (fluvial-lagoonal).

The Upper Guadalupe sandstone and the Lower Gualanday conglomerate can be correlated by the aid of pollenanalyses with similar horizons through-

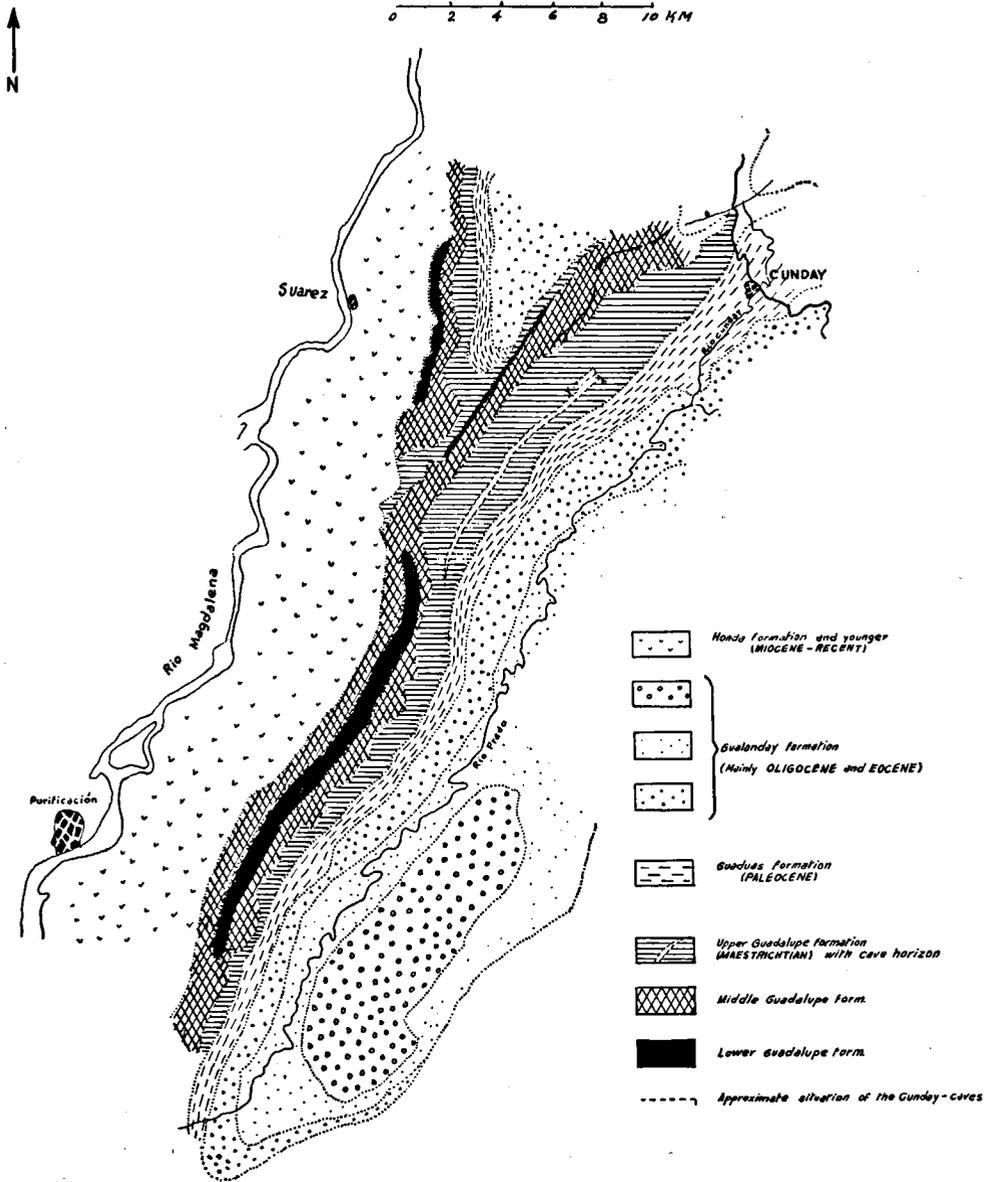


Fig. 1. Geological map of the cave region between Cunday and Purificación according to photogeological map of Tolima, by H. C. RAASVELDT (somewhat simplified).

out the whole eastern cordillera of Colombia¹. The Miocene Honda-formation is found only in the Magdalena-valley. The caves occur in the Upper Guadalupe sandstone. It consists in the Cunday region in its upper part of hard conglomeratic sandstone. Below this hard part are soft fine-grained sandstones, and still further down other hard sandstones, the latter forming the highest elevation of the Upper Guadalupe ridge.

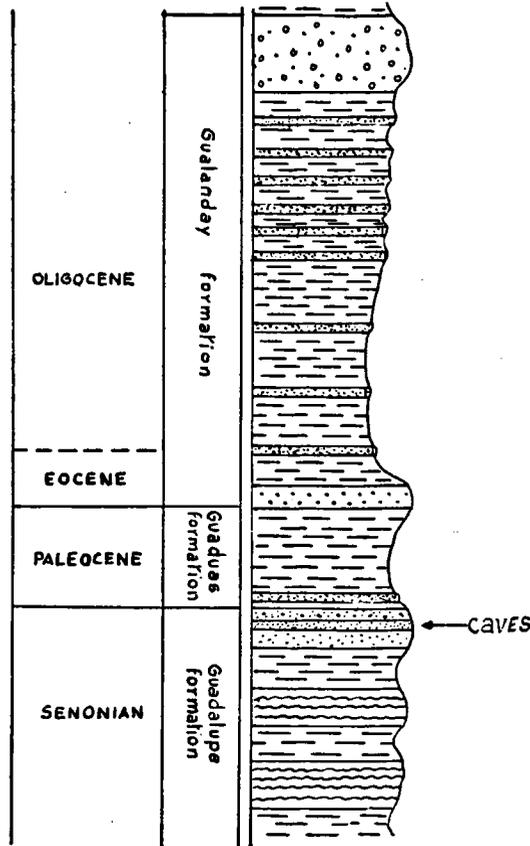


Fig. 2. Stratigraphical column of the cave-region south-west of Cunday (Dep. of Tolima, Colombia, S.A.).

¹ VAN DER HAMMEN, TH., 1954. El desarrollo de la flora colombiana en los períodos geológicos. I: Maestrichtiano hasta Terciario más inferior. Boletín Geológico, Tomo II No. 1. Bogotá.

3. *Description and mode of origin of the caves*

The caves are formed in a soft fine-grained sandstone-layer of the middle part of the Upper Guadalupe sandstone. They follow exactly the strike and dip of this sandstone. There are subterraneous rivers and springs. There are also various floors, but all are in the same sandstone-layer, which has a NE—SW strike and a dip of 25°—30°. Fig. 3 shows the position of the caves in the cordillera in the part we visited and fig. 4 shows a detail.

The height from bottom to ceiling changes in different parts, there are floors of only 50 centimeters and halls with a height of 10 and more meters. It is clear that the subterraneous water, circulating in the rocks by diaclases and stratification-planes, little by little carried away the sand of the soft fine-grained sandstone-layers forming "drain-gutters" in the strike of this layer. Once these channels were present, real water-streams and subterraneous springs could be formed, which could carry off the sand more rapidly removing continuously its course further down (and more to the SE, the dip direction). As is natural in caves, the water-streams may pass through an aperture to another floor. The water-streams seem to have their origin, at least for the greater part, in subterraneous springs and have in the part we visited a drainage from SW to NE.

Although the soft sandstone-layer has in general a thickness of not more than 2—5 meters there are sometimes "halls" of ten meters high and more. In these "halls" the floor is always covered with big blocks evidently fallen from the ceiling. We could clearly establish that these down-falls are originated by the existence of other, thinner layers of soft sandstone, present at relatively small distances (several meters) above the thick layer. When also these small layers are carried off by the water the ceiling becomes "floating", and falls easily down. The greater part of the down-fallen debris can be eroded more easily.

In some parts of the caves abundant stalactites and stalagmites of pure calcite occur, partly still in formation, showing the thin tubes with water-drops in the ceiling. But in the whole region there does not exist the least indication of limestones, and the sandstones from the ceiling of the caves do not contain any lime. However, the uppermost conglomeratic sandstone may have small quantities of lime in other places. So to explain formation of the stalactites we have to accept that the lime comes from this horizon, but has become already for the greater part lixiviated.

In several parts of the caves we found stalactites composed of other minerals, especially phosphorites. For the description of these and other minerals found in the caves we refer to the mineralogical part of the present paper.

In figs. 3 and 4 we give some block-diagrams showing the construction of the Cunday caves.

We can summarise the above in the following points:

- (1) The Cunday caves are of a different origin than the normal limestone-caves. They are not formed by the chemical solution of the rock, but by the removal of rock-particles through running underground water.
- (2) Thus, one or more layers of soft fine-grained sandstone, intercalated in harder sandstones, have partly been removed forming caves with the strike (NE—SW) and the dip (20°—30°) of the strata.
- (3) There are several floors, all in the same main soft sandstone-layer. The size of the caves ranges them among the larger ones of the world.

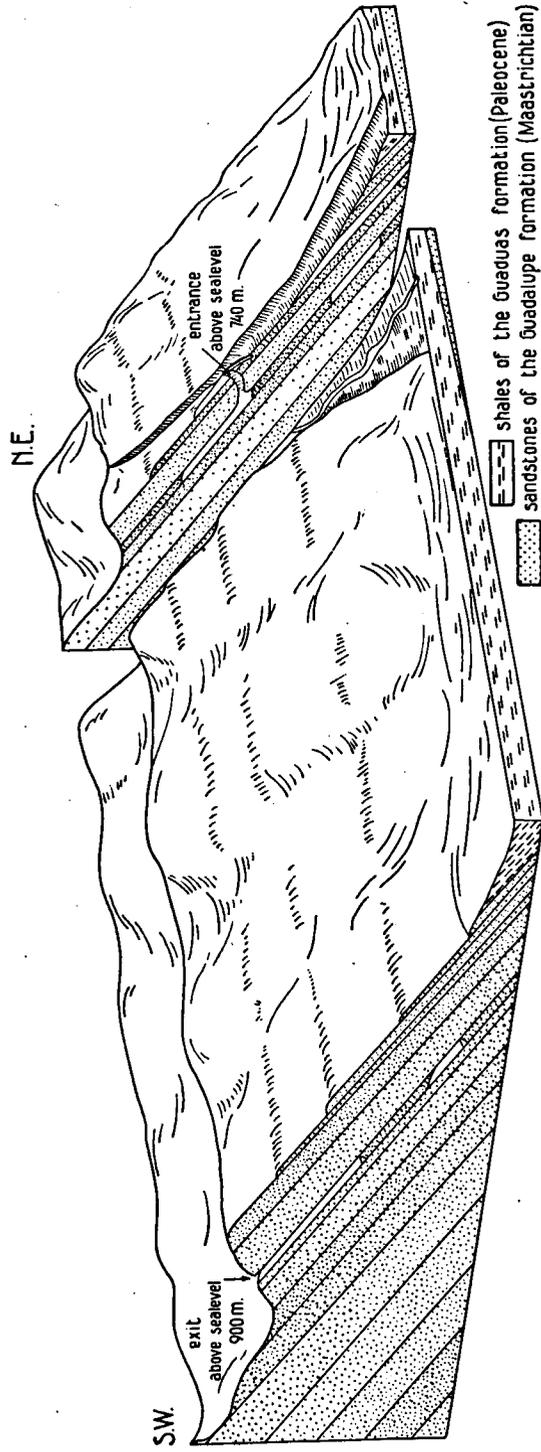


Fig. 3. Block-diagram of a part of the mountain-chain SW of Cunday (Dep. of Tolima: Colombia, S.A.) showing the situation of the caves. Horizontal scale approx. 1:15,000.

(4) High "halls" are present, although the soft sandstone-layer is not more than 2—5 meters thick. These halls were formed because the underground water also carried away smaller soft sandstone-layers above the main one, the ceiling thus becoming "floating" and then falling down.

(5) In some parts of the caves abundant stalactites and stalagmites occur, the first ones hanging on the sandstone-ceiling. We have to explain this phenomenon by lixiviation of the uppermost conglomeratic part or the Upper Guadalupe sandstone, which sometimes has a small lime-content.

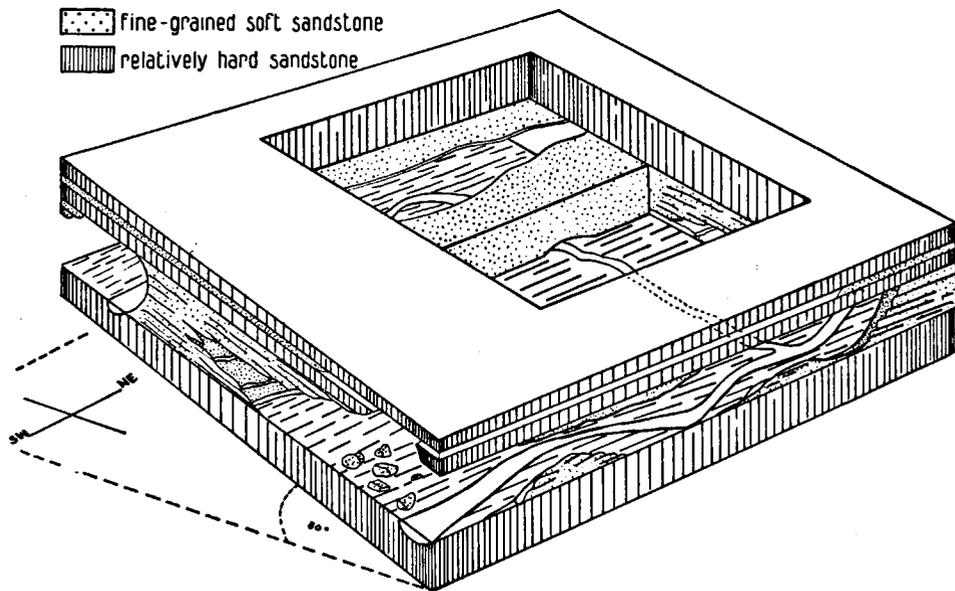


Fig. 4. Block-diagram of a part of the Cunday caves. The diagram represents a schematic section through part of the Upper Guadalupe sandstone (Maestrichtian). To permit to see the interior of the caves, an imaginary step-like section has been made, the first step is at the level of the ceiling of the caves, the second one at the level of the floor.

B. Mineralogical part (H. W. N.)

Among the samples collected in the caves during the exploration by the first author, some interesting phosphate minerals call special attention. In certain parts of the caves they cover the floor, form crusts on the walls or hang down as stalactites from the ceiling. Doubtlessly, these phosphorites are of organic origin.

The bottom deposits are generally banded in fine layers of different colour, varying from grayish to brownish tones, according to the amount of earthy impurities. They contain numerous pisolites with a fine concentric structure, up to 1 cm in diameter. The crusts on the sandstone walls are of a similar material; they show a faint radial fibrous structure, the fibres being perpendicular to the concentric layers.

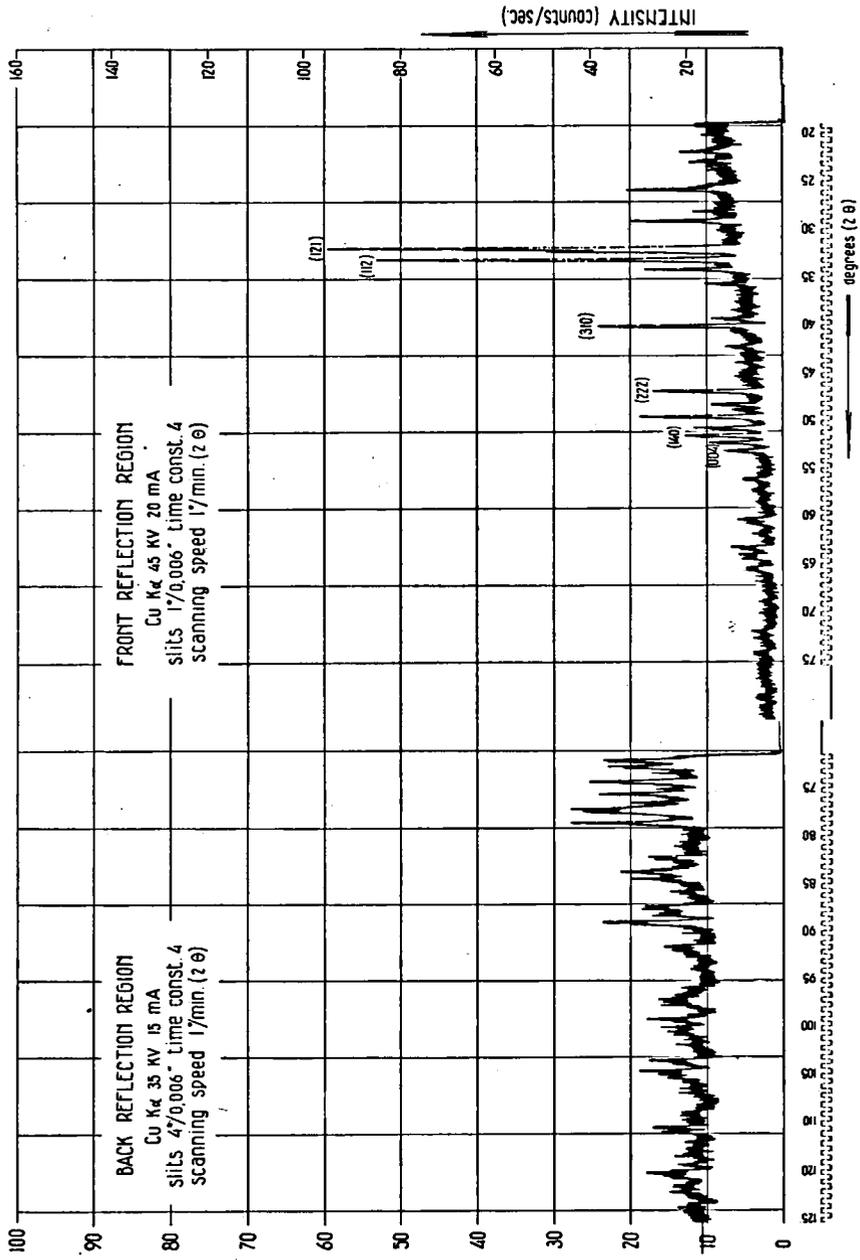


Fig. 5

More frequent seem to be ordinary calcite stalagmites and stalactites, which predominate in other parts of the caves. Also fibrous gypsum is present in small amounts.

The nature of the phosphorites was studied microscopically and by the aid of X-rays. In thin sections the concentric layers are clearly visible. Most of them have a fibrous structure, the fibres with negative elongation perpendicular to the layers. Birefringence is weak, ranging from approx. 0,005 to isotropic. In completely isotropic layers no fibrous structure can be observed any more. The refractive indices vary between 1,60 and 1,62, the isotropic parts having the lowest index. From these data we may conclude, that francolite (or staffelite) constitutes the main part of the phosphate rock, together with amorphous collophane. The pisolites commonly have a center of collophane, while the outer spheres are composed of radial fibrous francolite, showing a beautiful interference-cross between crossed nicols.

The impurities are mainly confined to small zones, and consist of fine sub-angular quartz grains. Sometimes a polygonal cell structure can be distinguished, which recalls vegetal rests, completely substituted by collophane and francolite. In this connection the presence of very small plants observed on the floor of the caves is interesting. Obviously these plants germed from seeds introduced in the caves by bats, whose guano and organic rests constituted the source of the phosphor. The absence of daylight prevented the normal development of these plants.

In order to verify the optical determination, some X-ray diagrams were elaborated. Fig. 5 represents the diffraction pattern of a finely banded part of the phosphate rock. It shows two records, one of the lower diffraction angles (19° to 75° , expressed in 2θ), and one of the higher diffraction angles, the so-called "back-reflection region". It is interesting to note, how the change of the aperture slits from 1° to 4° increases markedly the intensity of the diffraction peaks, of course with simultaneous increase of the background, caused by scattered rays and fluorescence effects. So, the weak diffractions at 72° and 74° become clearly visible in the back reflection record.

For more accuracy, the most important part of the diagram was repeated with a lower scanning speed. This detail log is given in fig. 6; it easily allows measurement of the diffraction angles with a precision of $0,1^\circ$, thus giving the d -spacings with an exactness within $0,01 \text{ \AA}$. The high resolution power at this low scanning speed is also nicely demonstrated in the $32,2^\circ$ diffraction, probably due to the not strictly monochromatic K_{α} -radiation and reveals the K_{α_2} -component, also seen in the higher diffraction-zone (47° to 54°).

For the interpretation of the d -spacings we disposed of the 1st and 2nd set of the ASTM card-file; the 3rd set, with two more data to the subject are as yet not in our possession.

In table 1 the most prominent diffraction lines are compiled and compared with the most alike data-cards of the ASTM-file, i.e. francolite and fluorapatite. The similarity of the pattern of these two minerals is striking. Indeed, complete substitution of Ca, P and O in the general formula of francolite $\text{CaF}(\text{Ca}, \text{C})_4[(\text{P}, \text{C})(\text{O}, \text{OH}, \text{F})_4]_3$ leads to $\text{CaF} \cdot \text{Ca}_4(\text{PO}_4)_3$, which is identical with the chemical composition of pure fluorapatite. Assuming that a crystallographic dimorphy of this substance does not exist (which

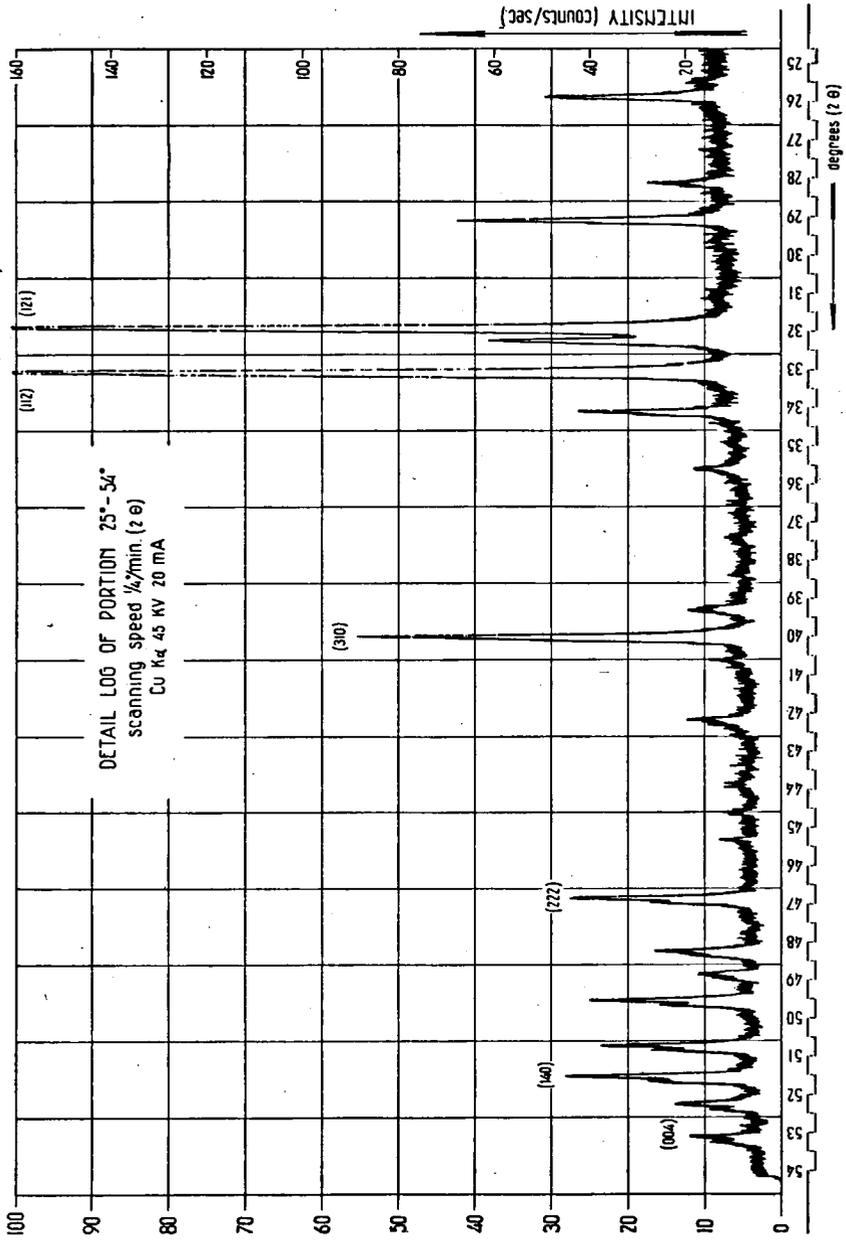


Fig. 6.

TABLE 1

Phosphorites of the Cunday caves			ASTM - data	
2 θ (diagram)	I/I ₁	d (calcul.)	francolite	fluor-apatite
25.8	25	3.45	3.44	3.44
29.1	30	3.07	3.05	3.05
31.8	100	2.81	2.79	2.78
33.1	90	2.70	2.69	2.69
34.1	20	2.62	2.62	2.61
40.0	40	2.25	2.24	2.24
46.8	25	1.94	1.93	1.93
49.5	25	1.84	1.84	1.83
50.8	20	1.79	1.80	1.79
51.6	20	1.77	1.76	1.76
52.3	12	1.75	1.75	1.74
53.2	12	1.72	1.72	1.71

undoubtedly would cause a much greater divergence of the diffraction lines of both types), we consequently may see fluorapatite as an end-member of an isomorphic francolite series. By substituting part of the O by F, the latter will become even richer in this halogene than the former.

In a recent publication of NIGGLI, OVERWEEL and VAN DER VLERK², on the relation of the age of fossil bones and its F-content, it was shown that the distance between the (140) and (004) reflections provides a valuable method to control the F-substitution in the fluor-hydroxyl-apatite-series. It appeared that these diffraction-lines move towards each other with an increase of the F-content. For synthetic F-apatite with 3,60 % F the distance of those lines was determined to be 2,76 mm, the exposure being made with Cu K α -radiation in a camera of 19 cm diameter. Pure hydroxyl-apatite, on the contrary, gave a distance of 3,15 mm.

Precise measurement of the (004) and (140) reflections in our diagram shows a difference of 1,58° (2 θ). In a camera of 190 mm diameter, this would result in a distance of:

$$\frac{1,58}{360} \cdot \pi \cdot 190 = 2,62 (\pm 0,02) \text{ mm.}$$

Although we are aware that the value of the above data is only approximate it seems justified to conclude that the examined phosphorites do not belong to the fluor-hydroxyl-apatites, but obviously to the francolite-series. The latter, as stated above, may have a higher F content than the pure fluorapatite, which would most probably result in a further approximation of the (004) and (140) lines, as is the case in our example. The francolite, reproduced in the data card (from the type locality Staffel, Germany) contains 4,1 % F, as stated in the chemical analysis, printed on the ASTM-

² E. NIGGLI, C. J. OVERWEEL and I. M. v. D. VLERK (1953), An X-ray crystallographical application of the fluorine-dating method of fossil bones. Proc. Kon. Ned. Akad. v. Wetensch., Series B, 56, No. 5.

card. A francolite, examined in the Geologic Institute of Leiden, showed only a distance of 2,175 mm between said lines. The fact that also CO_2 will enter in the francolite series constitutes an extra complication, the effects of which are as yet unknown. However, the above discussion may show how we made use of said reflections in determining the nature of the phosphorites.

Finally we have to mention a phosphatic mineral that occurs in small quantities in the ceiling of the caves. This mineral has a yellowish colour with a shade of green, and with a glassy lustre; its hardness is about 3—4. Microscopical investigation of the powder reveals that it is isotropic, with $n = 1,503$. Interesting is that thin sections proved a weak birefringence, in this way that between crossed nicols the material manifested a fibrous-flamboyant double refractive structure with positive elongation; the fibres seemed to traverse an original reniform and isotropic substance. The contradiction in optical behaviour between slide and powder specimen was soon resolved by heating some of the powder to 110°C . the approx. temperature used in the elaboration of the slides. The powder proved to loose crystalwater and turned double refractive, with index close to 1,46, showing the foresaid structure.

A partial chemical analysis gave:

36.84 %	P_2O_5
25.27 %	Al_2O_3
0.33 %	SiO_2
36.62 %	total loss at 900°C .

It is clear that the silica is due to impurities. The "total loss at 900°C ." probably represents principally water, considering the fact that there is no Ca and thus CO_2 as volatile component is not very probable. So, we can deduce an aluminium-phosphate of the approximate formula $\text{AlPO}_4 \cdot 4 \text{H}_2\text{O}$.

Up to now it has not yet been possible to identify this mineral, neither at base of its optical or physical properties, nor at base of its chemical composition. However, it seems to be related with evansite (or rosieresite).

X-ray investigations on the unheated powder proved its amorph state by giving no diffraction-pattern, while the heated powder showed some very faint diffraction lines.