[American Journal of Science, Vol. 250, November 1952, Pp. 822-828]

A MEGABRECCIA FORMED BY SLIDING IN SOUTHERN FRANCE

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ABSTRACT. In the south of France amidst the Tertiary plain of Alès a series of hills is found built up of a breccia of Urgonian and Hauterivian limestones, lying disconformably upon Lower Tertiary. The occurrence appears to be analogous to the occurrence of a megabreccia in Nevada and Arizona, described by Longwell (1951), the origin of which is explained by sliding. This principle can also be applied to the breccia found in France.

INTRODUCTION

IN the Tertiary plain of Alès in the south of France a series of hills is situated, built up of a breccia of Lower Cretaceous limestones and marls (fig. 1). These hills have been studied by French geologists since 1880. Apart from some conceptions out of date, there were two quite different theories about the origin of this breccia. During the summer of 1951 the author spent three months in the area in order to test by detailed mapping the existing theories.

Longwell (1951) describes the occurrence of large remnants of megabreccia in southern Nevada and western Arizona. As there appears to be, irrespective of the age of the formations, a striking similarity between the occurrence of Longwell's megabreccia and the breccia-occurrence in the south of France, Longwell's observations will be briefly quoted first, and at the end of this paper an attempt will be made to apply his explanation to the breccia in the plain of Alès.

OCCURRENCE OF MEGABRECCIA IN WESTERN ARIZONA

According to Longwell the breccia is exposed in an area about 6 miles long from northwest to southeast, with maximum width nearly 3 miles and lying upon Tertiary lavas and Miocene basin deposits. On the eastern side the area is bordered by the high ridge of the Black Mountains, composed of Precambrian gneiss, schist and granite. The entire mass of typical breccia consists of broken rock. Some individual fragments are hundreds of feet long; there is no matrix of clay or other fine-grained weathering products. The fragments making up the breccia were derived from Precambrian bedrock—gneiss, schist and granite like those in the Black Mountains complex, which is the one

logical source of the debris. In general the body of breccia, up to several hundreds of feet thick, is unassorted and wholly chaotic. The underlying Miocene silt, gypseous clay and gravel beds are remarkably little disturbed. At a few localities only

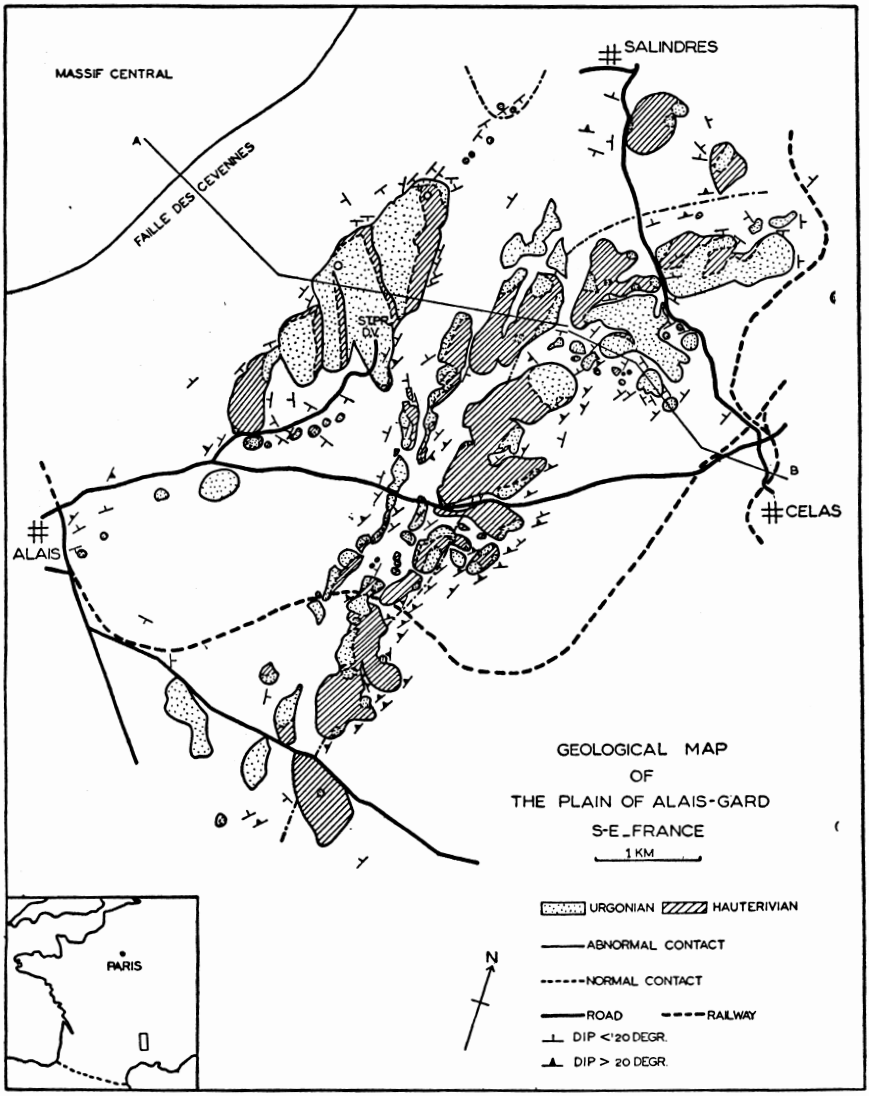

Fig. 1. Geological map of the Tertiary plain of Alès, showing the Hauterivian and Urgonian breccia. A-B, line of section, figure 2.

the layers directly beneath the contact with the breccia are crumpled. Commonly the contact surface is smooth and carries striae, trending generally with the slope.

The west base of the Black Mountains is marked by a zone of faulting, with upthrow of the Precambrian block on the east.

The coarse debris of Precambrian rock was derived from the Black Mountains, as indicated by its distinctive lithology, and is interpreted as a landslip mass, the front of which moved at least 5 miles from its bedrock source.

OCCURRENCE OF MEGABRECCIA IN SOUTHERN FRANCE

The plain of Alès is a fault graben with maximum width of 7 kilometers (4.4 miles) and extending in a NNE-direction for about 45 kilometers (28 miles) parallel with the eastern border of the crystalline "Plateau Central" (Cevennes), which is covered by Carboniferous, Triassic, Jurassic and Lower Cretaceous deposits (figs. 1, 2). This massif is separated from the plain by a fault system, mainly consisting of normal

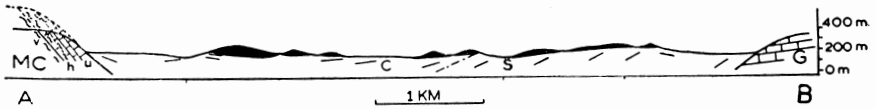

Fig. 2. Geologic section along A-B, figure 1. Vertical scale same as horizontal. MC, Massif Central; G, Garrigues; black, breccia; v, Valanginian; h, Hauterivian; u, Urgonian; C, Chattian; S, Stampian.

faults, called "Faille des Cevennes," which has a NNE-direction. The breccia in the southern part of this extensive plain is found only over a distance of about 11 kilometers (7 miles).

The Lower Cretaceous covering the eastern border of the Plateau Central consists of Valanginian marls and Hauterivian limestones and marls, characterized by *Toxaster amplus*, being therefore indicated in French literature as "Marnes à Toxaster" (M.à.T.). The M.à.T. are overlain by white and yellow Barremian limestones (Urgonian facies). These limestones are hard and compact.

This M.à.T. and Urgonian builds up a NNE-ridge, which rises more than 130 meters above the Tertiary plain. The whole of the Lower Cretaceous has a dip of 45 degrees to the southeast, i.e., valleyward.

At the eastern border of the Plain of Alès are situated the

PLATE 1

Fig. 1. Detail of breccia of Urgonian limestone. Note striae on the block to the right and angular form of the block to the left.

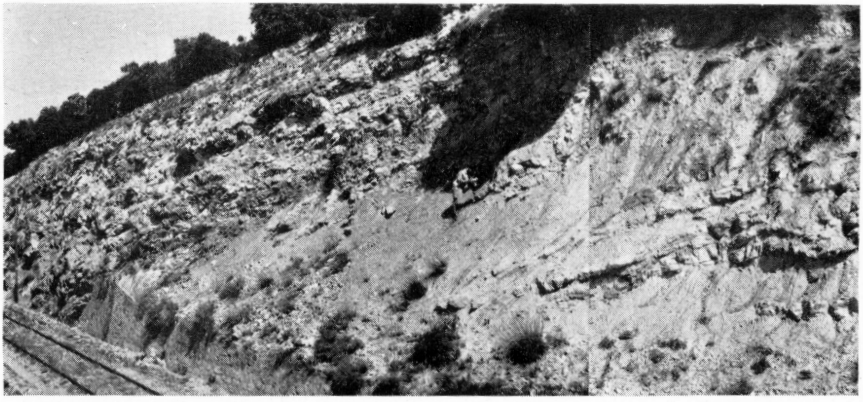

Fig. 2. Section along the railway in the middle of the plain of Alès, showing undisturbed bedded Oligocene gravels and marls in the foreground (right) overlain directly by the chaotic breccia of Urgonian limestone in the background (left).

View, looking north, of one of the hills, built up of the breccia of Urgonian limestone, in the midst of the flat Tertiary plain. In general there is a gentle dip slope to the west and a steep wall to the east. In the left background the breccia hill of Saint Privat des Vieux can be distinguished and in the right background another series of hills of the same breccia.

Garrigues, separated from the plain by a fault system. The Garrigues consist of Lower Cretaceous limestones which have been intensely folded during the Eocene perpendicular to the fault system. The fault-graben of Alès between the Plateau Central and the Garrigues is filled with Oligocene sediments (gravels and marls) which all dip 10° to 30° westward. There are some counterdips, which may be explained, as shown later, by the emplacement of the overlying breccia mass.

The highest part (Chattian) of the Lower Tertiary deposits in the graben of Alès contain mainly Urgonian pebbles, and the lowest part (Stampian) contain also quartz and schist pebbles. The boundary between these two formations is indicated on the map by a dot-dash line.

In the middle of the fertile and cultivated plain are situated a great number of hills and ridges (one hundred meters high), built up of the breccia of Urgonian limestones and layers of M.à.T., which are brecciated too. Since 1880 French geologists have tried to give an explanation for this more or less strange occurrence of hillocks of Cretaceous limestones and marls in the midst of the Tertiary plain. Some believed these hills were the tops of islands piercing through the overlying Oligocene. In 1919 Termier and Friedel considered the hills as remnants of an overthrust mass, that would have covered the whole area. On the geological map they are still called "klippes" and the breccia is compared with a mylonite. This theory is now abandoned by all geologists.

More recent investigations have been executed by G. Denizot (1931, 1937) and J. Goguel (1936). Denizot divides the occurrence of the breccia mass into two groups, namely the big hill of Saint Privat des Vieux (a village) and the small hills to the northeast and southwest of it in the western part of the plain on the one hand, and the row of hills in the eastern part on the other (fig. 1; plate 2). Denizot assumes that the breccia mass of the hill of St. Pr. d. V. has a root. In other words it is piercing through the Oligocene. The same would apply to the small hills.

After exhaustive fieldwork in 1951 the author cannot agree with this opinion and believes the mass (about 50,000,000 cubic meters) is lying upon the Oligocene. The main facts upon which his opinion is based are: 1) Along the western border of the hill the Tertiary dips under the breccia; the contact is clearly

visible. 2) There are two windows, one on the northern and one on the western part of the hill, in which the Oligocene is exposed beneath the Cretaceous breccia. 3) If we had to do with bedrock in place, the superposition Urgonian/Hauterivian would be maintained rigorously. Near the village St. Pr. d. V. one can observe, however, that the breccia, mainly consisting of Urgonian limestone, contains among these blocks also big blocks of Hauterivian limestone. 4) Denizot himself mentions a drilling in the Tertiary, which was executed between the hill of St. Pr. d. V. and the small hills southwest of Salindres. At a depth of 260 meters the Cretaceous was not yet reached, so if these hills were the tops of islands, the slopes must be very steep (at least 45°). In the eastern part of the area Denizot considers the breccia masses as bedrock in place too, but to explain the superposition of the breccia upon the Tertiary over a distance of more than one kilometer he assumes the existence of thrust faults of low angle (less than 30°). In my opinion, the superposition of Cretaceous breccias upon the Oligocene deposits can be followed over a distance of more than four kilometers from west to east, or over the whole breadth of the occurrence.

The author can agree with the opinion of J. Goguel (1936), to the extent that the latter does not consider the breccia as bedrock in place. However, Goguel assumes that the breccia of Urgonian limestone is interstratified in the Oligocene. Goguel assumes for the hill of St. Pr. d. V. that the breccia is lying upon the Oligocene. He connects the hills in the eastern part of the area in such a way, that they belong to four layers of a breccia of Urgonian limestone, which are interstratified in the Oligocene, and which could be followed over a distance of some kilometers. So according to Goguel the breccia is sedimentary. The difficulty for Goguel is to find the origin of the elements of the breccia and the way of transport by which the normal sedimentary process was interrupted at least four times by the deposition of these breccias. Because blocks of many tons are not rare, neither river transport nor a mudflow can be responsible for the sedimentation. Glacial transport is excluded also.

Finally Goguel ventures to remark that on the western side the plain is bordered by a fault system, which was active during the deposition of the Tertiary. There might be a certain rela-

tion between the sudden affluence of the brecciated Urgonian and the different periods of activity of the fault.

Now the author's observations will be briefly summarized. All over the area the brecciated Urgonian and Hauterivian limestones and marls are lying more or less unconformably upon the Tertiary. There is no reason to separate the hill of St. Pr. d. V. from the hills in the eastern part. So, we have nowhere to do with bedrock in place. Neither is there any reason to connect the different hills in order to get continous layers of breccia. Although erosion will have removed part of the original mass, it is very questionable if there has ever been a continuous covering. Mostly the breccia is wholly chaotic (plate 1, fig. 1 and fig. 2), although to a large extent the superposition Hauterivian/ Urgonian is maintained. The discrete blocks of various sizes are imbedded in a matrix made up of small fragments, all of the same Cretaceous formations. The breccia ranges up to 40 meters thick, but commonly the thickness is less. In some places the Urgonian lies directly upon the Oligocene gravels and the M.à.T. are missing. The large fragments at the lower part of the breccia carry striae, trending generally with the slope (plate 1, fig. 1). The underlying Oligocene marls and gravels are somewhat disturbed. Although in general the dip of the Oligocene is to the west (10° to 30°), there are some counterdips in the eastern part of the area in front of the breccia masses, which must be explained by thrusting. Perhaps the eastward dip along the western side of the hill of St. Pr. d. V. can be explained by compaction of the Tertiary under the weight of the overlying breccia mass.

CONCLUSION

Thus there is a striking similarity between the occurrence of this breccia and the occurrence of the breccia described by Longwell. The only logical source of the brecciated material is the Hauterivian and the Urgonian bedrock of the Plateau Central. Because the dip of the formations there is very steep (45°) plainward, it can be assumed that the breccia masses in the plain originated by landslides of material shed from the relatively rising Cevennes. The Hauterivian marls served as a lubricant. In the plain one can observe numerous recent small-scale landslides of Urgonian breccia over Hauterivian marls. Whether we have to do with a chronic or a catastrophic slide

is doubtful. In this respect the great Turtle Mountain slide at Frank Alberta in 1903 (C. F. Stewart Sharpe, 1938) is very suggestive. The mountaintop stood some 3100 feet above the valley and was composed of massive limestones thrust over a much younger and softer series of sandstones and shales. Movement was initiated on a well-developed system of joints, which dipped valleyward at an angle of about 40 degrees. The rock-slide-rockfall rushed across the valley over a distance of 2.4 miles (4 kilometers) and 400 feet (122 meters) up the opposite wall. It is estimated to have carried down 35 to 40 million cubic yards of rock (26 to 30 million cubic meters). The quantity of breccia now present in the plain of Alès is estimated to be 150 to 225 million cubic meters, and has been spread across the Tertiary plain of Alès over a distance of at least 2.4 miles (4 kilometers). Whether or not we have to do with a sudden or with a chronic sliding cannot be said for certain, yet there cannot be any doubt about the slide origin. In this slide the stratigraphical sequence of the rocks has not been disturbed, apart from local imbrications and wedging out of the marls at the base. Urgonian limestone breccia is still resting on top of the Hauterivian marls.

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