NOTES ON THE GEOLOGY OF BALYA MADEN

Tore GJELSVIK

United Nations, Expert

ABSTRACT — Data from a reinvestigation of the old lead mine of Balya Maden in western Turkey are compared with those of earlier studies. The complicated tectonics of the area is tentaiively explained as a result of recumbent folding during the Alpine orogeny. A rough calculation indicates that the mineralization occurred at a depth of 1 600 - 1 900 m below the (Tertiary) surface.

INTRODUCTION

The mines of Balya Maden are well known to Turkish geologists as the main producer of silver- bearing lead in Turkey in the period of 1880 to 1935. Unfortunately, very little has been written on the interesting geology of the mine (BUKOWSKI 1892, KOVENKO 1940). In 1956, when exploring the mineral deposits of the Biga peninsula, I found it necessary to reinvestigate the Balya area. Shortly after my arrival at Balya in the spring, a private mining Company started a geological and geophysical exploratiori of the old mine area. I hope that the detailed studies now being done, will lead to a new life for the mine and to a complete understanding of the intricate tectonic Problems of the area. My own studies to some extent fill the gap between the special mine investigations and the interesting stratigraphical and tectonic studies recently published by AYGEN (1956), and although I could not spend enough time in the area to reach decisive conclusions I hope this account will contribute to a better understanding of the problems.

STRATIGRAPHY AND TECTONICS

The rock formations occurring in the Balya area comprise :

— Permian limestone (and arkoses?),
— Triassic shales, sandstones, and conglomerates,
— Tertiary volcanic rocks.

According to AYGEN, the limestone should be the only Permian formation within the Balya area proper. To the north and northwest, however, he reports Permian arkoses overlying the limestone. In the road - section on the top of Sarısu hill, a short distance south of the village, I found an arkosic rock, containing small conglomeratic beds, that is intercalated in the limestone. I did not find any fossils in it, but in the conglomeratic series imroediately west of the village, along the Çan chaussee, I found some fossils in the matrix which, by the paleontological Service section of M. T. A., were determined as Permian. The conglomerate contains many and large pieces of limestone, identical with the underlying (Permian) one, and it is possible, though in my opinion not probable, that the fossils also are detritus. AYGEN *(loc. cit.* pl. I) considers this conglomerate to be Triassic, but it is quite different from the other exposures of Triassic rocks. Especially, it contains layers of true arkoses that are unknown in the Triassic formations in this place.

The Triassic rocks comprise dark pelitic shale, layers of sandstone, and a calcareous conglomerate series. Towards the sandstone, the shale gradually gets more sandy, and therefore more greyish-brown. This series is exposed mostly to the east and northeast of Balya, and in the Bahgeler valley the shales, sandstones and conglomerate apparently dip under the Permian limestone. In AYGEN's opinion the Triassic sedimentation represents a *regression,* and the superposition of the Permian limestone is caused by thrusting during the Alpine orogeny. His opinion is illustrated in fig. 1 below, which is a reproduction of fig. 2, p. 33 in his paper.

Thus Aygen arrived at a conclusion opposite to BUKOWSKI's, who maintained that the Triassic sedimentation represented a *transgression,* that the conglomerate was a basal formation, and that the Bahçeler valley was a syncline. In their maps, both authors give dip signs supporting their respective tectonic solutions. BUKOWSKI considered the shales and sandstones met with in the Arı mine to be of the same age as the limestone. Apparently, at the time he wrote his paper, no fossils had been found in them, and he was aware of the possibility of Triagssic age, remarking *(loc. cit.* p. 224) that, in such a case, rather complicated disturbances had occurred. KOVENKO *(loc. cit.)* describes them as Triassic formations. During my visit, the An mine was flooded, and I could only inspect the mine dumps, which showed pieces of the characteristic Trias conglomerate.

The tectonics of the area is truly complicated. The following events and features have to be considered :

—- Hercynian folding etc. of the Permian formations,
— Alpine folding, faulting (including thrusting),
— Displacement of rocks during extrusion of lavas,
— Lateral inconsistencies of sedimentary facies, as well as repetition of facies with time.

In the Balya area, I have found fold axes of at least 2 systems, one having approximately N-S azimuth, the other E-W. Whether they are contemporaneous or not I cannot say, but such pairs of fold axes are often found within the same orogen. Faulting is frequent, KOVENKO *(loc. cit.)* lists 3 different sets. A study of the mine maps gave me the impression that, after all, the vertical displacements due to faulting within the mine area have not

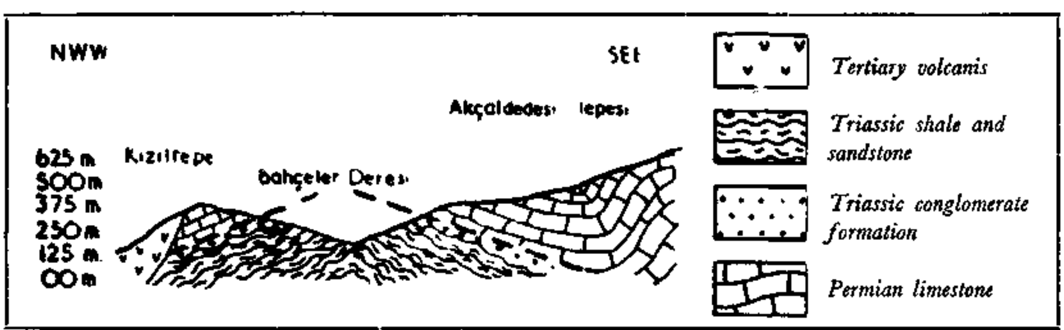

Fig. 1 - Profile Kızıltepe - Akçaldedesi Tepesi

been important. (Displacements at low angle to the bedding would of course not easily show up on the maps.)

During the winter 1955/56, I was— by the courtesy of the Ministry of Economics— able to study more than 60 mine maps from Balya Maden, most of which were level maps from two major mines, An and Orta. Unfortunately, the maps contain no structural data, they are in most cases purely lithologic maps. By constructing vertical E-W profiles, however, I found some important structural features. Fig. 2 represents one of the most complete profiles, and demonstrates that :

The strike generally is N or NE, but local variations are frequent. AYGEN only records gentle or moderate dips in his tectonic diagrams, but in the hills of Kızıl Tepe and Asarlık Tepe the conglomerate series in most outcrops shows nearly vertical dips. In one location, however, in the eastern slope of Kızıl Tepe, the Permian limestone rests on the conglomerates with a moderate dip (30° to the S, thus the strike also is at variance with the general one). In the field I got the impression that the amplitudes of the folds in the conglomerate series were of a small or moderate size. Even less reliable are the

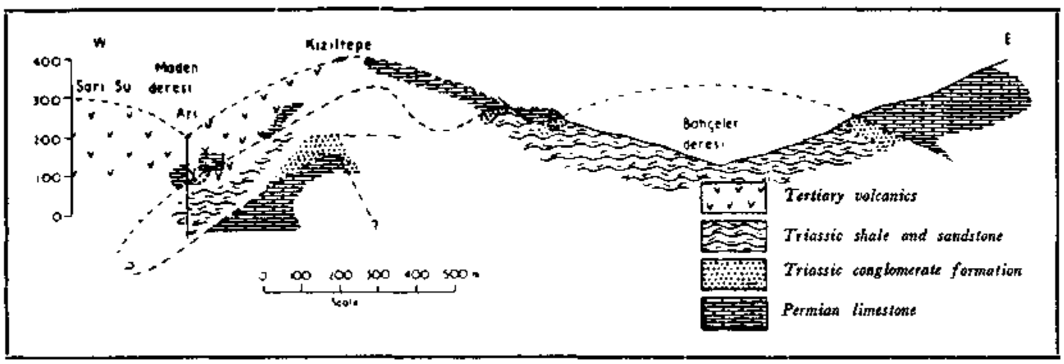

Fig. 2 - Profile Arı shaft - Kızıltepe - Bahçeler valley
(The left part constructed from mine maps, the right part from Aygen's profile - fig. 1)

1. In the mines, the Triassic series are in the hanging of the Permian limestone (i. e. in normal succession).

2. The Triassic rocks are repeated, and they exhibit a certain degree of symmetry, indicating an overturned fold. This conclusion, however, rests on the assumption that only *one* series of shale and conglomerate is present within the mine area. As outlined above, this assumption may not be valid, and I hope that the current investigations will answer this important question.

For several reasons, the strike and dip of the schistose formations give no decisive clue to the tectonic problems.

structures of the shales, which often are crumpled and sheared. Thus east of the river in the Bahçeler valley, just south of the village, AYGEN and BUKOWSKI record opposite dip of the shale. In this place I found a number of small folds in a generally flat-lying formation. The Permian limestone, as described by AYGEN, is generally massive. Schistose structures are met with at several places, but most often they represent parting planes of tectonic origin. I also recorded schistosity planes cutting bedding.

Summing up, from the local attitude of the various formations, no reliable tectonic picture can be obtained, at least not without a long and exhaustive investigation.

Before I started the field work at Balya, AYGEN generously made an excursion with me in the area. He then demonstrated the above - mentioned locality in the eastern slope of Kızıl Tepe, in which place the Permian limestone is overlying the Triassic conglomerate formation. At this place, the limestone contains brecciated limestone in small bands within a zone of 50 m thickness. This, in AYGEN's opinion, is caused by the overriding of the limestone. I was, however, struck by the absence of tectonization of the immediately underlying conglomerate, which consists of rounded quartz and chert pebbles. Neither was I convinced of the tectonic character of the limestone breccia. Unfortunately, heavy rains prohibited a detailed study on this occasion. Later, I returned to the place for a close investigation. I then found that the quartz pebble conglomerate is intraformational in a sandy limestone series containing scattered pebbles. Upwards the sandy limestone also contains a few layers, only dm to 1 m thick, of breccia limestone, and finally the breccia beds alternate with ordinary limestone beds. In fig. 3- I have reproduced the contact between the pebble conglomerate and the overlying limestone breccia bed, which is seen in a good exposure only a couple of meters from a little creek. The pebbles are represented by black squares, the breccia fragments by triangles, without consideration of the size of the fragments. It is seen that, although the contact is rather sharp, scattered pebbles of quartz occur in the limestone breccia, thus demonstrating a sedimentary transition. No shearing phenomena can be seen. A few meters above, the contact of another breccia bed and the sandy limestone is exposed, and it also demonstrates a normal sedimentary contact. Thus I was unable to find a tectonic break in the series above the pebble conglomerate, and in my opinion, the limestone breccia is of sedimentary, not tectonic origin. At other places, I did note tectonic breaks *under* the conglomerate series, at the top of the shaly sandstone, that probably represent faults of subordinate importance.

In Taf. I in BUKOWSKI's paper a drawing is reproduced of the contact (at Kızoluk Bunar) of the (Permian) limestone and the conglomeratic sandy

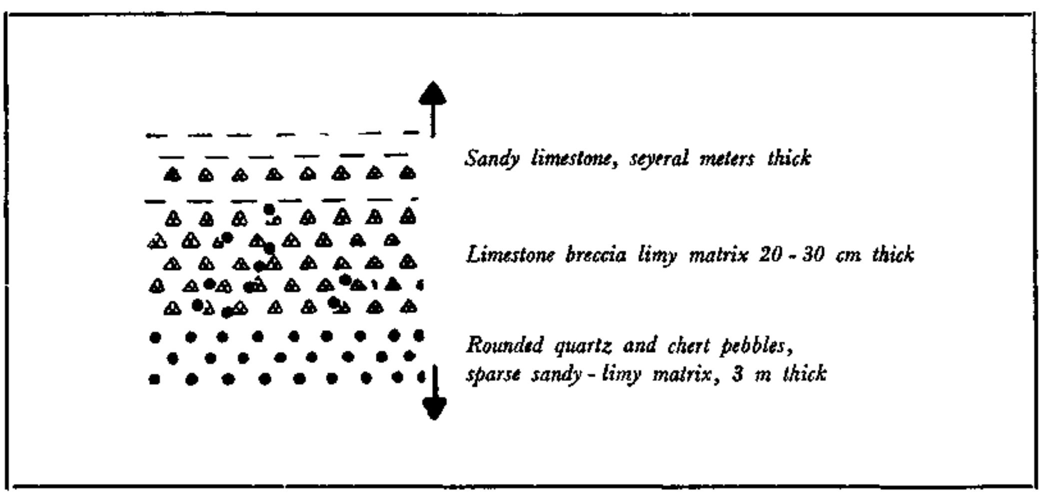

Fig. 3 - Sketch of breccia/conglomerate contact, Kızıltepe

limestone, that, if correctly made, definitely proves that the latter has been deposited on the former by a transgression of the Triassic sea. My own observations corroborate this conclusion.

Although I could make controls only a few places, I feel rather convinced that, generally, the Permian limestone is superimposed on the Triassic series, as maintained by AYGEN, in the outcrops around Bahçeler valley. In AYGEN's opinion this is the result of an overthrust by pressure from E or SE. In order to bring this tectonic solution in accordance with the mine profile (Fig. 2, left part), the thrust-plane must be folded as to form a recumbent fold whose axial plane dips towards NW. This, in my opinion, is difficult to obtain by a pressure from E or SE. It would seem a remarkable coincidence, also, that the formations, after thrusting, should be brought back to normal position, *at depth,* by folding.

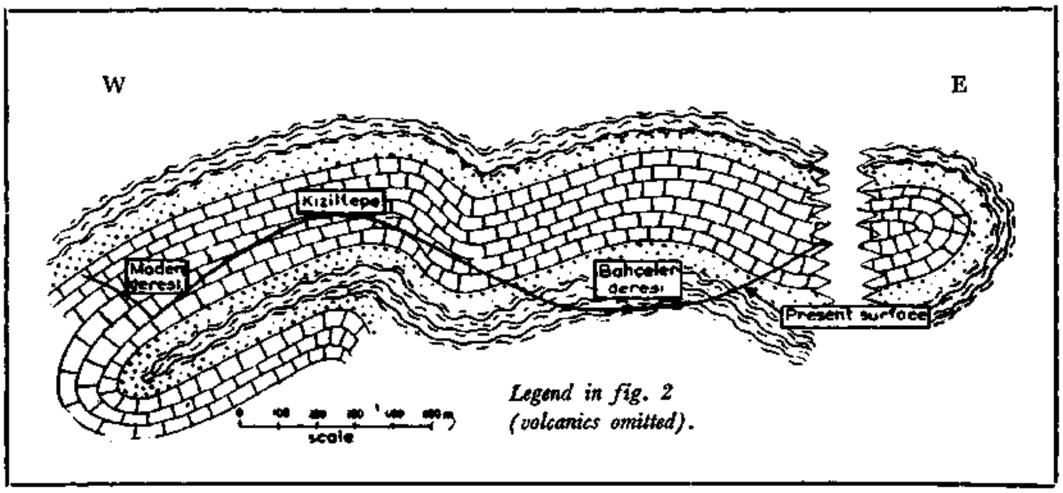

Fig. 4 - Profile of supposed recumbent fold, Balya

I therefore would like to offer for consideration an alternative tectonic solution: The superposition of the Permian limestone is brought about by an immense recumbent folding of trie,formations towards E or ESE. This implies a pressure from the opposite direction as that proposed by AYGEN. The upper part of the recumbent fold has been eroded at a later stage (see fig. 4). Recumbent folds of this size are well known in the Alps, but, as far as I know, not yet reported from Turkey.

In order to decide which solution is correct, it is necessary to establish the chronological succession of the Triassic sediments. If it can be proved that the conglomeratic, sandy limestone formation represents the top of the series (i. e. formed during regression), the solution offered above is ruled out. This formation should be closely inspected for sedimentary structures like cross - bedding, graded bedding etc. During my studies, I found some such structures S of Kızıl Tepe, which unfortunately, were not amenable to definitive interpretation.

It is worthy of notice that, if my tectonic interpretation is right, the large volcanic outbreak at Balya, which preceded the ore formation, occurred in the very root-zone of the recumbent fold.

THE VOLCANIC ACTIVITY AND MINERALIZATION

The Balya lead-zinc ore presents a very good example of subvolcanic mineralization. Different types of ore occur (KOVENKO, *loc. cit.),* but they are all closely connected to the volcanic rock or its contacts with the sediments. Because of the inaccessibility of the mines at the time of my visit, and the lack of visible mineralization at the surface, I have very little to add to KOVENKO's description of the ore types. His outline of the tectonics is in some respects incomplete, however, and AYGEN's maps are purposely of somewhat general character, e. g. they do not distinguish between volcanic dikes and lava flows.

As already mentioned, the mineralization is localized along the contacts of a great dike, or sill, which has intruded on the hanging side of the supposed Arı-Orta fold, and which is about 1 km wide and several km long. The An and Sarısu mines are located at the southern end of the sill, in which place it splits into several small dikes trending S and SE. Apparently, most ore was found along the smaller dikes. The great sill is multiple, as it consists of dacite or liparite-dacite, cut by dikes of andesitic composition. The latter are most abundant along or near the contacts of the great sill. Similar mineralization in other parts of Turkey is known to be related to the latest, and generally the most acid volcanic rocks (WIJKERSLOOTH 1946). For Balya, KOVENKO states that the andesite dikes cut the ore, and thus must be younger. In the little valley leading down to the Arı mine from the village, strongly pyritized andesite dikes are exposed, and thus the relation of the mineralization to the volcanic activity must be quite complex at Balya.

Whereas andesite occurs in distinctly separate dikes, no clear contact can be seen between the liparitic and the dacitic parts of the great sill. This may be due to the strong decomposition of these two rock types at Balya, but perhaps there are primary variations in the petrographic composition of the great sill. In the extrusive series occurring above, only rocks of dacitic or andesitic composition were found.

The extrusive series starts with a thin flow of dacite, followed by thick agglomerate beds with homogeneous fragments, also of dacitic composition. Higher up come tuffitic beds with scattered blocks, and alternating beds of coarse agglomerate and andesite flows. The matrix of the agglomerate is greatly altered, whereas the dacite blocks are surprisingly fresh, thus much better preserved than the intrusive dacite. In the former, the phenocrysts of plagioclase, biotite and horblende are unaltered, in the latter, the plagioclase phenocrysts exist only as relics, and biotite and hornblende are all gone. This may be the effect of late magmatic fluids (whether ore-bearing or not) using the dikes as channels on their way up. It may be worth while to study the bleaching effect closer, to see if it can be used as a guide to ore. Another guide, besides the structural and petrographic ones, may be a fluorine (fluorite?) concentration in the walls of the galena veins. In a specimen, taken near a 10 cm wide pyrite-galena vein, 0.5 % F was found, whereas this element is practically absent in the other samples which were chemically analyzed.

Since the deposits of Balya seem to be typical samples of subvolcanic mineralization, it would be interesting to find out the depth of the mineralization. The most intense mineralization probably occurred at an altitude of 0 to 300 m. The trace of the Tertiary surface, on which the extrusives were deposited, is to be found 600 m W of the square of the village of Balya, at an elevation of 270 m. The volcanic beds dip 30° to the west. If this, as a rough approximation, is taken as the inclination of the Tertiary surface (peneplane?) also, the thickness of the pre-Tertiary crust above the An mine would amount to 800-1 000 m. If it is correct that the mineralization occurred before the andesite outburst, and if the first andesite flow represents this event, a dacite agglomerate pile of about 500m thickness may have covered the surface at the time of mineralization. The mineralization, then, occurred at an actual depth of 1 600-1 900 m. Now the lead deposits of Balya Maden probably belong to a transition stage between epi- and mesothermal deposits, as shown by the existence of grossular garnet among the gangue minerals of the deeper levels. Thus the figures arrived at above appear reasonable, despite all the uncertainties related to the calculation.

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