

A GEOLOGICAL ROUTE THROUGH CENTRAL ASIA MINOR

FROM AFIUN KARA HISSAR VIA SIVRI HISSAR, ANGORA,
SUNGURLU, AND THE MALYA TCHÖL TO CAESAREA

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The following paper is the summary of a series of notes taken in the summer of 1907, in connection with the Cornell Expedition to Asia Minor and the Assyro-Babylonian Orient. In a worked-over area like most of Europe and the United States, such a series of observations, probably somewhat inaccurate because of their hurried character, would add little to our knowledge. But in central Asia Minor the case is far different. Travel has been difficult and travelers are few. The men who have studied the geology of even a part of central Asia Minor could be numbered on one's fingers, and but one or two of them had the advantage of being trained geologists used to the work and to the country, and with the leisure to stop and examine.

For this reason it is that these notes represent new territory in practically their whole length. At certain points only did we cross (geologically) known territory.

The observations were taken from horseback, as had to be done under the conditions of travel. It was rarely possible to stop to investigate a place or to visit again one that had been passed. This must have resulted in some errors, especially as the caravan could not carry any great weight of specimens.

Frequently the rocks were fossiliferous, making their date certain, but unconformities were so frequent that it was not wholly safe to consider surrounding rocks as of the same date as the fossiliferous strata. Specimens were preserved wherever fossils were found (the majority were Eocene nummulites). These are deposited in the museum at Harvard and a study of them by

specialists would certainly result in a more accurate dating of many strata.

Because of the peculiar conditions the description will usually follow the itinerary of the party, which was as follows: Afiun Kara Hissar,¹ Phrygian Monuments, Aktash Köpri, Sivri Hissar, Gordium, Polatly, Hammam (Haimané), Giaour Kalesi, Angora (Enguri), Assi Yuzgad, Yakshy Khan, Izz-ed-Din, Sungurlu, Boghaz Köi—with a sidetrip to Eyük—Yuzgad, Medjidié, across the Malya Tchöl to Bash; Hadji Bektash, Kara Burun, Avanos, Inje Su, and Caesarea (Kaisari). At this point the author was obliged to leave the party and hurry back to Constantinople. A few notes were taken from the train north of Afiun Kara Hissar which have been used to help out the map of that section.

Distances are reckoned roughly in hours (at the rate of a walking horse, three miles an hour), as that is the usual unit of measurement in the country.

The principal geologist of Asia Minor was Tchihatcheff,² and his map remains the only one of much of the country. His work is now fifty years old and an experienced modern student would doubtless modify much of it. Still to the present time the man who has his books at his elbow will not miss very much of what is known of the geology of the eastern two-thirds of the territory.

Yuzgad, and on an even grander scale, Caesarea, are in the center of regions which should prove exceedingly interesting. The complex resulting from several periods of igneous action makes a fascinating puzzle to disentangle. At these points I can add almost nothing to Tchihatcheff's account, but can fully verify the existence of the confusion he reports.

Because of the impossibility of determining the date of most

¹ I have not been entirely consistent in my transliteration of native names of places, etc. There is no established method, and two books on the country will hardly agree in their methods. *I* and *y* (vowel), in particular, represent different sounds in Turkish, but they are not sharply defined and I should perhaps have used *y* more freely than I have. The distinction between *q* and *k* also generally represents a mere difference in Turkish spelling. *Q* might perhaps have been used more freely, following Arabic precedent.

² I follow the spelling of Tchihatcheff's name as it appears on the title-page of his large work—in French. It is spelled differently in the German reports of his travels.

of the rocks, they are classified on the maps rather from superficial characters. I have specially indicated the points where fossils have been found. The rocks may be grouped as igneous (of various sorts), metamorphic (largely Paleozoic where their relationships are known), obliquely stratified (Mesozoic and Eocene, especially the latter), and horizontally bedded sedimentaries (Miocene and later as a rule). Thorough tracing-out of the relationships of strata and thorough collecting of the fossils can alone give a much more accurate knowledge of the dates of the various deposits of Asia Minor.

In connection with the regular archaeological report of the expedition I expect to publish this matter in a less technical way and with reference rather to its interrelation with the various past peoples of Asia Minor and their culture.

I wish to express my indebtedness to the members of the expedition in many ways, and especially to Jesse E. Wrench, who did most of the topographic work; also to Professor J. B. Woodworth, under whose direction and advice this report was prepared, and to the other authorities of Harvard University who have helped me in the matter of books, instruments, etc.

MOUNTAINOUS PHRYGIA

Comparatively few notes were taken in this district, and no specimens were collected. The substratum of the country is metamorphic, appearing as schists along the railroad cut between Ihsanié and Düver (Deuyer), at the entrance to the mountainous section southwest of Ayaz In, and in smaller bands east of Yazili Kaya. There were also three outcrops in the Sakaria plain, one a considerable band at the eastern end of the Yazili Kaya limestones, and the others east and west of Aktash Köpri, as shown on the map. Quite as frequently the metamorphic rocks were limestones. This was the case along the railroad, north of the mapped area for a considerable distance, and also in a large area all about Yazili Kaya.

Overlying the metamorphic rocks are everywhere igneous rocks, Neocene in date. These lie in horizontal beds, lavas, or tuffs, and are sometimes so rotted as to be indeterminable. Of the

same period also are several local deposits of sandstone and conglomerate. These are cut by the railroad near Hammam and elsewhere; they form the basis of many of the sculptured rocks of the country. More frankly volcanic are the white tuffs of Ayaz In, and the lava mesas which make a dominant feature of the landscape east of the railroad, and all about Yazili Kaya.

The lacustrine gravels of the Sakaria Valley approach quite close to Yazili Kaya on the east and mark the northeastern boundary of Mountainous Phrygia.

As reported by Tchihatcheff and Hamilton the region south of the author's route is of the same character, but the dominance of igneous rocks becomes less. The conspicuous volcanic necks of Afun Kara Hissar are well described by Tchihatcheff and others.

THE SIVRI HISSAR RANGE

Passing over the lacustrine plains of the Sakaria River for the present, we reach the next point of interest in the Sivri Hissar Mountains, conspicuous among them Kodja Bel. At this place the stratified rocks would seem to belong to the same group as those in Phrygia, but the core of the range is a granite (a syenite in the popular sense of the word, as it is a fine-grained granite with little or no mica). East of Bala Hissar there is an area of limestone on the very top of the range, surrounded on both sides with the syenite, apparently lifted up on top of it. Near the city (Sivri Hissar) there is a complex of metamorphic rocks (schists and gneiss), through which the road passes on the east side of the mountains. Kodja Bel, a conspicuous peak southeast of the city, and the Kaimas peak to the northwest, seem to be similar.

Tchihatcheff has reported on the northwestern part of the range; conditions are essentially the same, an alternation of syenite (granite) with various metamorphics.

GORDIUM AND POLATLY

The neighborhood of Polatly, unlike the preceding localities, has fossiliferous rocks, making it possible to fix this district as *Eocene*. Nummulites are the dominant feature, as elsewhere in Asia Minor eocenes.

To the west of the Sakaria no Eocene rocks were found *in situ*, but the cairns built by the shepherds are of fossiliferous limestone.

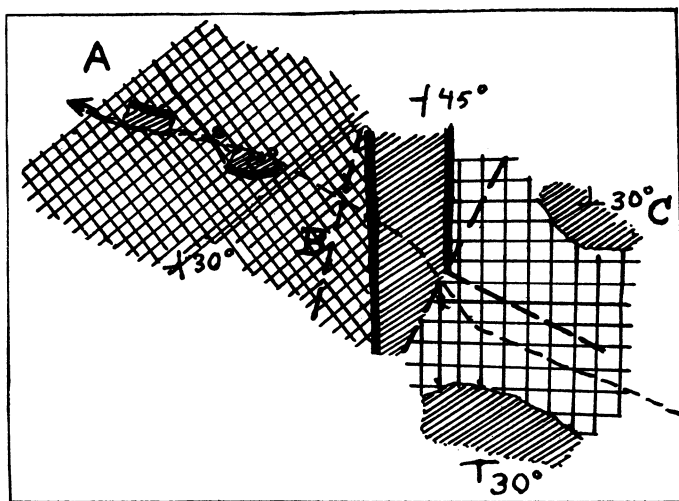


FIG. 1.—Sketch of the hills southeast of Gordium, interpreted as a laccolith. The stratified shales are indicated with fine oblique hatching; the lower trap is coarsely, and the upper trap finely, cross-hatched. The baked layer of the shales is shown solid black. Possible faults are indicated.

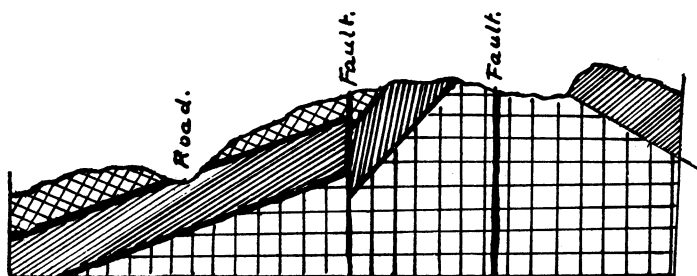


FIG. 2.—Cross-section through ABC. The symbols are the same as in the preceding figure.

Probably outcrops of the rock occur. On the east side of the river the lacustrine plain is quite narrow, and is replaced by hilly country. This is composed, to the south of Polatly, largely of Eocene limestones, but farther north of light-colored (yellow or

greenish) shales, which have the appearance of hardly consolidated clays.

There were also many outcrops of a dense igneous rock, necks southwest and east of Polatly, and sheets nearer to the village and to the northwest. To the northwest, as the plan shows, the situation becomes quite complex; in the plan the strata are interpreted as representing a laccolith, with overlying sedimentary rocks and flows, sloping away in at least three directions from its uncovered core. The eastern part was, unfortunately, passed over in the night, so that I cannot say whether the conditions were the same on that side or not. Overlying the sedimentary rocks was a sheet of lava. This had baked the clay red for the thickness of about a foot, making a very conspicuous layer. The red color was quite extensive toward the north, east of Gordium, so probably the trap sheet had once been much larger, but has been eroded off, leaving only the baked brick layer as a memento. At present, of course, these deposits can only be marked as "probably Eocene."

Hamilton reports similar mixtures of sedimentary and trap rocks north of Polatly, in the neighborhood of "Begesch" (Bey-djez or Beikos?).

HAIMANÉ

Separated, at least in the line of our route, by a region of recent deposits, from the Polatly limestones and shales, there lies to the east the strikingly arranged Haimané district. In the immediate vicinity of Hammam no fossils have been found, though the rocks (shales) look promising enough. At Kaya Bashy there were plenty of shells in a limy conglomerate, apparently largely *Anomias*, but they were so much injured in transport that one can hardly determine whether the rocks belong with the eocenes of Polatly, or with the Jura and Lias which other authors have reported to the west of Angora. While Tchihatcheff, who has passed through the district at right angles to our route, considers them as probably Jurassic, I should incline rather to the other conclusion, especially as some of the Polatly nummulites were in quite similar-looking rocks.

At any rate, they are sedimentary deposits, obliquely banded,

very brilliantly colored in red and yellow, and rarely obscured by plant cover, so that their bedding can be traced for long distances. No unconformities were noticed, but the point of transition between the shales immediately about Hammam and the calcareous conglomerates and sandstones to the north was not seen. As reported by Tchihatcheff these deposits must be very extensive to the north of our route; in fact they and others similar dominate the formations of central Asia Minor.

A gorge about an hour north of Hammam, near the village of Arif, passes through a mass of much denser limestone, which seemed to be conformable to the other deposits, but was very different in appearance. It is indicated by heavier hatching on the large map.

Giaour Kalesi is close to the boundary between the series of sandstones just described and one of the great plains that make the type-landscape of central Anatolia. The boundary runs northeast and southwest, and was followed most of the way from Hammam Merkes to the Hohan Göl. The castle itself, however, is on a pinnacle of very different rock, more similar to those which wall the gorge at Arif and also to those at Angora and Assi Yuzgad. It may then be of the same period as the surrounding rock, or with the Angora series, much older. There was no noticeable continuation of it through the surrounding rolling country. All the apparently earlier walls of the castle were built of it. The stones were small and yet show no great signs of weathering, in marked contrast to the condition of Boghaz Köi, also built of its local marble during the same period of history. Less than an hour east of Giaour Kalesi is the village of Oyaja, built about the base of two trap necks, like a miniature Angora. These, or other similar outcrops, furnished the material for the later heaviest walls of Giaour Kalesi.

Looking off from the top of Giaour Kalesi the hills seemed spotted with deep green, the characteristic mark a little farther east of the serpentines, and here doubtless due to the same cause. The spots seemed to have no regular arrangement and perhaps marked small volcanic necks, which, being soft, did not project above the general level.

THE ANGORA DISTRICT

In the neighborhood of Angora I first came across the confused mass of rocks that seems to be typical of the igneous areas of Asia Minor. We stopped some time at Angora, and a day at Ortaköi, near by, giving rather more opportunity than usual to study the conditions. The series that leaves the strongest impression with one is a group of schists, extending roughly northeast and southwest, alternating between dark schists with hornblende or mica, sometimes very dense, and a very friable, whitish type, which seemed to have talc or sericite for its foundation (a snap-judgment, as there was of course no opportunity to go back). Neither of these types had the superficial appearance of stratified rock, but the relation of the two schists to each other and to the limestone of Elma Dagħ convinces me that they were originally sedimentary. Tchihatcheff calls the whole system serpentine, and considers it igneous. They were apparently interrupted by a lava flow from Angora, southeast of the city where Tchihatcheff crossed the Elma Dagħ, but the clay-slates, "Thonschiefer," on the road south from Angora, would seem to belong to the same bed; at least they have the same relation to the limestone.

I crossed the entire width of the schists, going a few rods north, and three miles south, from Ortaköi. South of Angora the Thonschiefer were of about the same width.

The marble was traversed in two places, and was also noted by Tchihatcheff about half-way between these two, giving a good idea of it. It seems to form the whole crest of the Elma Dagħ and may extend quite a little farther at each end. Hamilton and Tchihatcheff's notes would however seem to indicate that it is limited by Jurassic sandstones to the southwest, and apparently to the northeast also before reaching the Kyzyl Yrmak. Might the coalbeds reported near Kalejik, on the Kyzyl Yrmak, belong to the same system? To the north the schists were very soon cut off by igneous rocks of various kinds, but Hamilton reports both schists and limestones again north of them for some twenty miles northeast from Angora.

The most typical of the igneous rocks are the necks which rise in Angora itself. These are of a reddish or purple trachytic

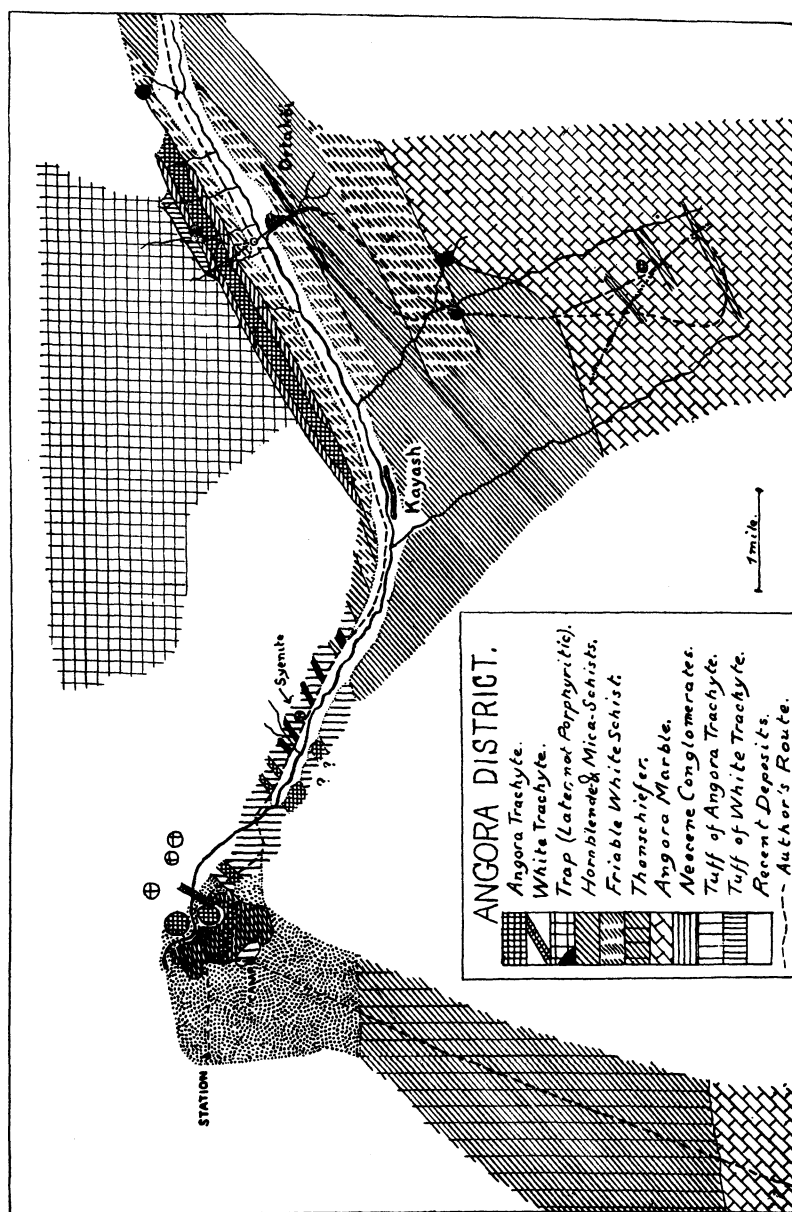


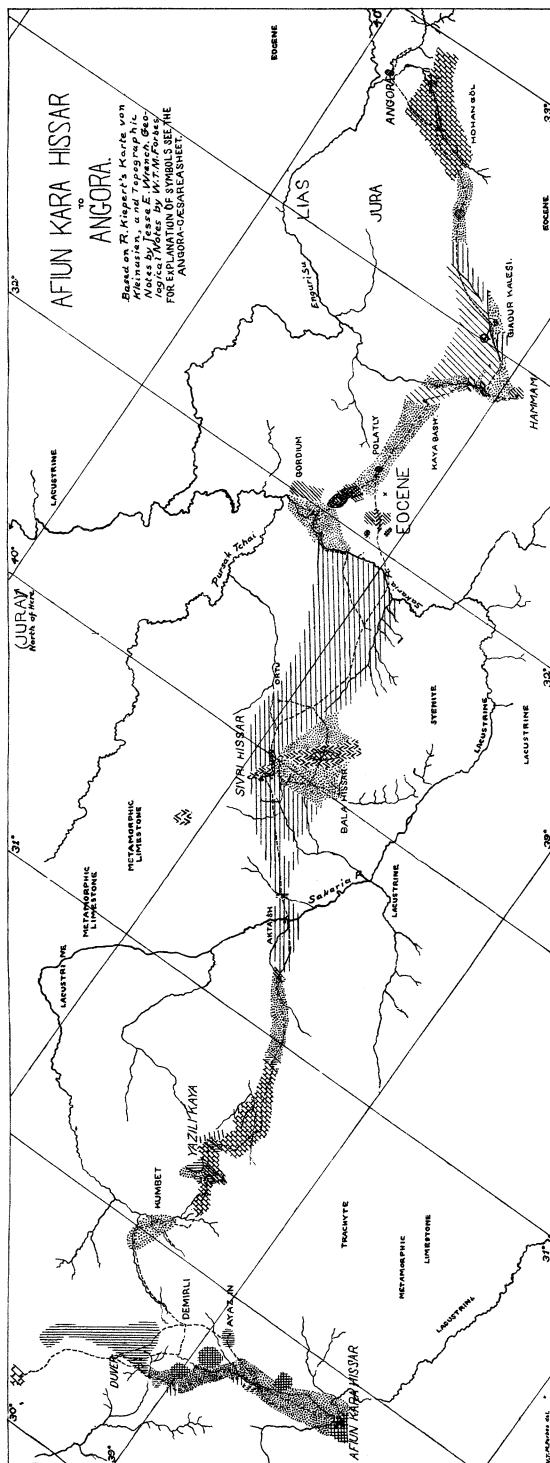
FIG. 3

porphyry.¹ The tuff which covers large areas east of the city, and makes the hill west of it, is made of the same volcanic rock. North of Ortaköi there is a long outcrop of the same type of rock, apparently here a lava flow, interbedded between two layers of late conglomerates, which in their turn have been made up of the schists, etc., of the region, and also of a fine-grained sandstone evidently not very old. Over the upper bed is a layer of white tuff, which one would naturally associate with the trachytes at Angora, and over this again a flow of very dark trap of indefinite extent. This trap would seem to make all the mountains to the north, at least for some distance. There are also dykes of it cutting all the earlier beds, and necks of it north and northeast of Ortaköi. There is a small neck of the Angora trachyte also penetrating the limestone three miles south of Ortaköi.

To sum up, there seem to have been the following periods of deposit: (1) the system of limestones and schists which were probably metamorphosed and eroded before the next period; (2) the sandstone which formed an element of the conglomerates, and so must have had time to become consolidated before the date of the eruptions; (3) the eruptions of Angora trachyte, forming also the white, and porphyry tuffs (during lulls in this the conglomerates north of Ortaköi were deposited by the precursor of the Enguri Su); (4) the period of the dark traps. Since the last there has been time for the whole landscape to be eroded down to its roots, leaving even the latest volcanic rocks as necks, and flows which have been tilted to decided angles.

Almost a continuation of the Angora complex is the district about Kylyjlar. Just north of Assi Yuzgad there is a volcanic mass, apparently a sheet extending northward. Soon after reaching the hilltop the marbles about Assi Yuzgad, which have dominated since the last watershed west of the town, are in their turn replaced by an area of dense dark volcanic rock, mostly altered into serpentine, which extends, with various admixtures, almost

¹ Bukowski has studied the igneous rocks of this district at some length. He finds the dominant rocks to be a variety of andesite, with quite a number of other igneous types, however. So probably the so-called trachyte and trap of the older geologists of Asia Minor should often be interpreted rather as andesite. He traces the extent of this igneous area to the north. See the Bibliography.



to the Kyzyl Yrmak. For the first couple of miles it is interrupted by several reappearances of the marble. Two of the hills south, also, are crowned by later horizontal beds. The dominance of the serpentines gives the whole country as far as one can see a deep green tint, varying in spots to pale green and to liver-red. After crossing a broad alluvial plain without outcrops, and then a narrow ridge of volcanic rock similar to the deposits to the west, we reach the immediate vicinity of Kylyjlar.

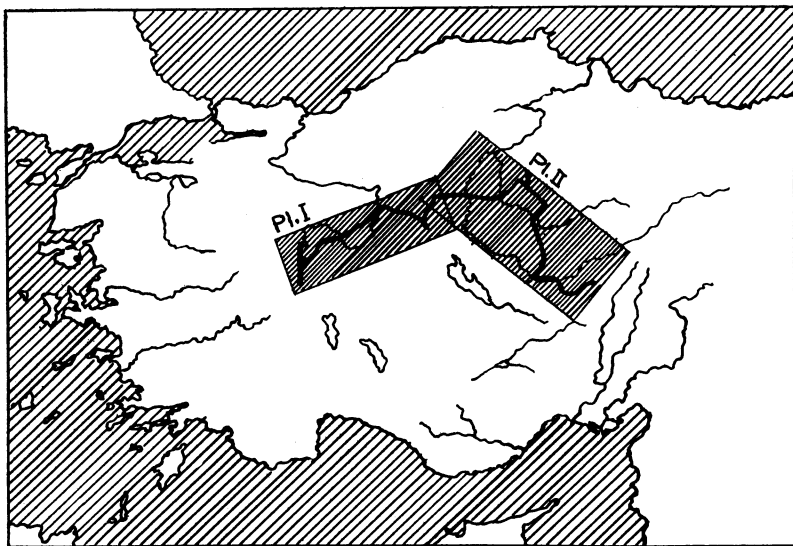


FIG. 4.—Index map of Asia Minor.

On the east slope of the last ridge west of Kylyjlar, there is a small outcrop of schist, dipping steeply to the northwest, and similar to that east of Angora. Underlying it is a small patch of syenite, not indicated on the map, and east of that again a flat-topped hill that dominates the whole valley. This hill seems to be formed of the serpentines, but is capped with a layer of the gray and white Angora limestone, apparently originally continuous with the beds east of the valley. East of Kylyjlar the dominant rock is still the same serpentine, but with the denser type less common, and more mixed than before with the greenish white tuffs (?). For a mile immediately east of the town, however, it

is clearly a tuff with large pieces of the dense volcanic rock as a foundation.

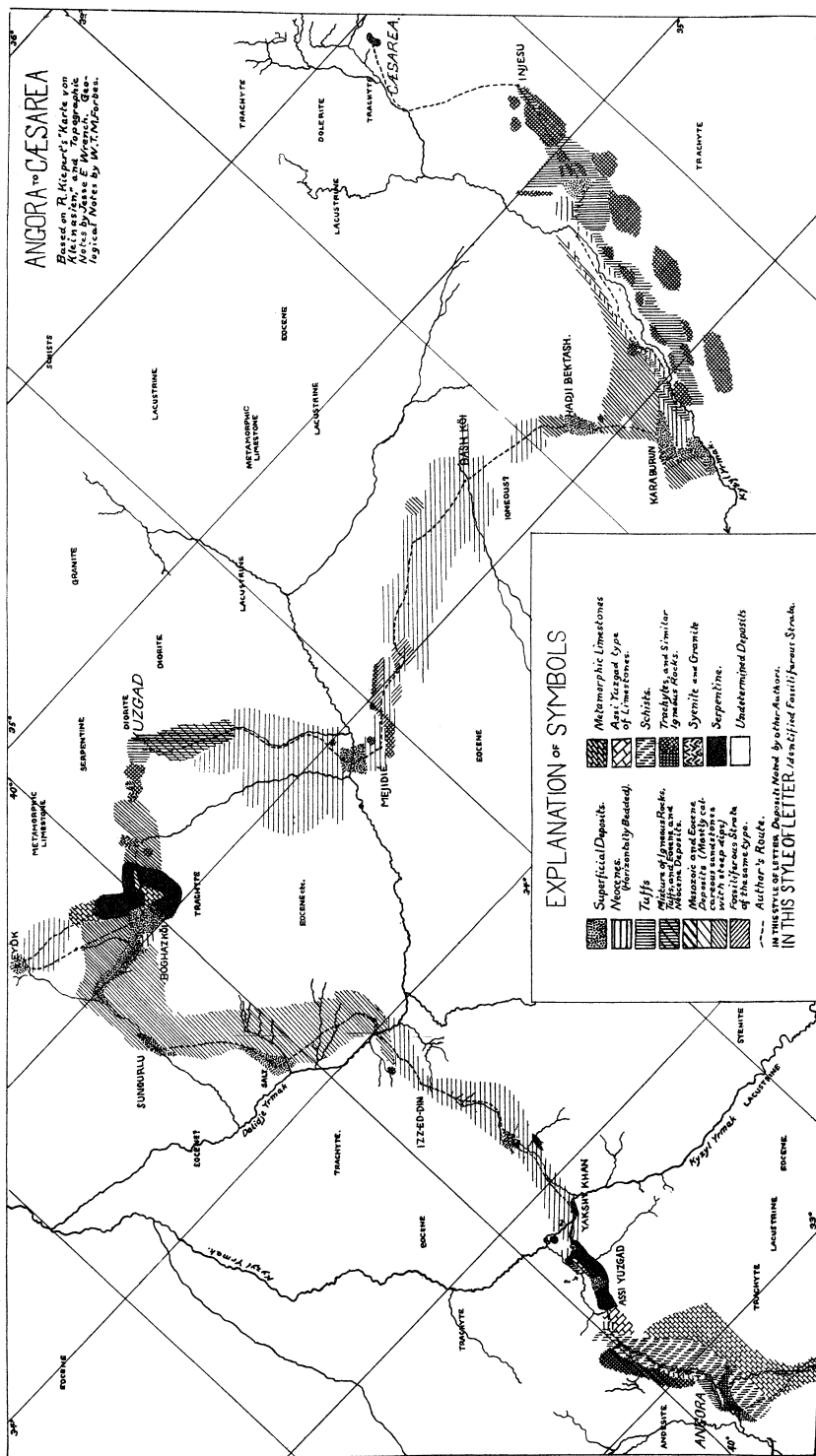
Interbedded with this tuff there comes in quick succession a series all dipping northeast: in order going eastward, conglomerate, Angora limestone, tuff, limestone, tuff again. There is also a very conspicuous line of the pale-green rock running south behind Kylyjlar, parallel to the valley. I did not find its contact with the stratified rocks, possibly a dyke of some kind. The marble appears in several other places between this district and the Kyzyl Yrmak, and also (but here the white crystalline type we found about Assi Yuzgad) in a prominent hill just across the Kyzyl Yrmak.

Two miles east of Kylyjlar the serpentines east of the path are replaced by syenite, but they continue south of the syenite, and underlie the Neocene rocks for a distance farther. On leaving the syenites, now only a long mile from the river, we ourselves strike into the Neocene deposits that fill the bed of the river and extend indefinitely eastward. The neocenes are an alternation of conglomerate, sandstone, and a fine-grained rock like pale-brown sugar (perhaps the "saccharine limestone" of Tchihatcheff). The latter is well exposed immediately around Yakshy Khan and seems to be the top layer of the series.

THE SUNGURLU SERIES

The section between the Kyzyl Yrmak and the Delidjé Yrmak is dominated by Eocene deposits. However, here and there igneous masses were seen, and they were probably numerous off of our route. Apparently serpentines form considerable outcrops south of Yakshy Khan, along the west bank of the Kyzyl Yrmak, and about a third way to Izz-ed-Din it again becomes probable that the distant rocks to the south are serpentines. An hour northeast of this last deposit there is a very conspicuous outcrop of syenite, cut from east to west by a crooked gorge which serves as a road. Immediately north of Yaghly there is evidently another igneous outcrop abruptly cut off to the south by a small brook, in a way that suggests the possibility of a fault running northwest and southeast.

East of this line, almost as far as Eyük, and from there south



to Yuzgad, rocks of Eocene facies were constantly in sight, the immediate vicinity of Boghaz Köi making the only serious interruption. In the immediate vicinity of Aktché Köyün our route took us out of this Eocene area into the lacustrine plain which so often accompanies the larger rivers of Anatolia.

The rocks of Eocene facies dip at various angles, and do not seem to be entirely conformable. However, as in unquestionably conformable series in that vicinity the dips and strikes often change very abruptly, I should not dare to say that more than one period is represented. One may take, for instance, the case sketched here. This is a frontal view of a bluff, past which the

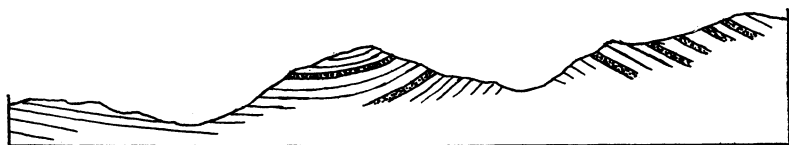


FIG. 5.—Frontal view of a bluff a short distance east of Alembeyli, showing very rapid change in dip of the strata. The stippled layers represent gypsum; the rest is sandstone. The road passes through the right-hand depression. (Somewhat diagrammatic.)

road ran (through the central gap, in fact). The entire part of the ridge shown in the figure was but a few rods long, and as one can see, the dip of the strata has changed considerably. Actually aside from this anticlinal structure the whole series dipped away moderately. At this particular point, near Alembeyli, there was some tendency for the dips to be moderate and easterly. Southwest of Aktché Köyün the dips of the nearer strata were about the same, but some strata were seen dipping at angles of over 45° . As already mentioned the two sets *appeared* unconformable but this may have been because of inability to see the intermediate rocks.

At Sungurlu, at the east end of the village, there is a thin bed of plant remains, but they proved too fragile for transport.

BOGHAZ KÖI

The dominant rock at Boghaz Köi is a marble breccia, with a bright red cementing material, making a striking pattern. Occasionally the marble is more massive, and then may appear either

like the Angora or the Assi Yuzgad types, showing that the latter two can well be of the same date.

Mixed all through with these marbles is a serpentine, in which, wherever the outcrops are clear, the marble appears to be floating

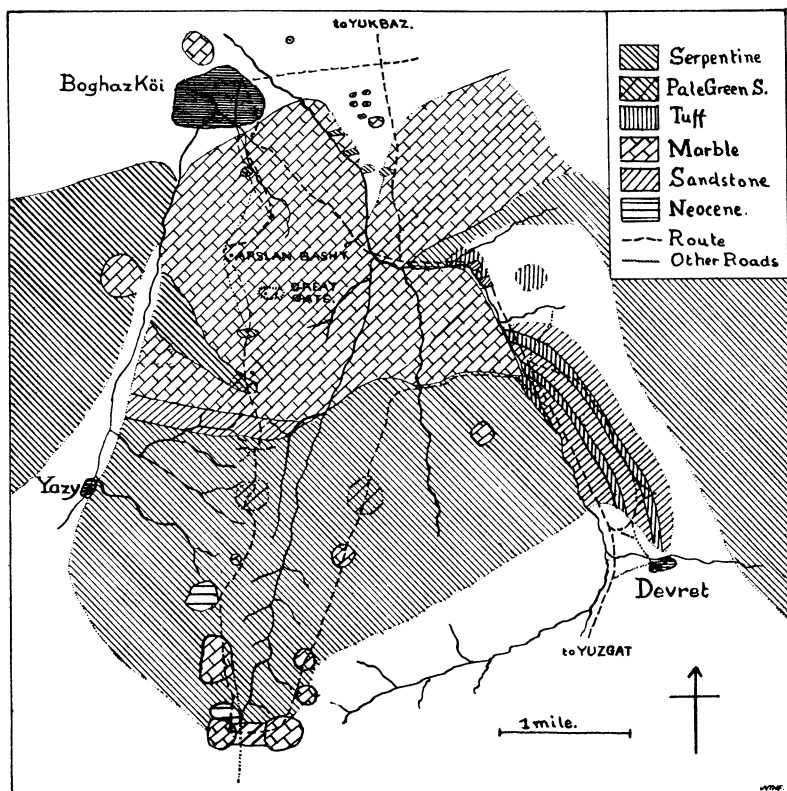


FIG. 6

in large blocks. The serpentine is less in evidence immediately under the ruins at Boghaz Köi, but even there the excavations have exposed it enough to suggest that the arrangement is the same.

At the point where the dominant limestones give way to serpentines, as one goes south from the village and the ruins, there is an east-and-west bed of a dense siliceous rock that also appears

a second time farther south, interbedded with sandstones. In both cases the dip is northeast.

Farther east and up the main valley as far north as Devret the rocks and their arrangement are different. Here there are two bands of a dark tuff, with fragments of vesicular trap, imbedded in sandstone, and the whole dipping to the east. Where we went,

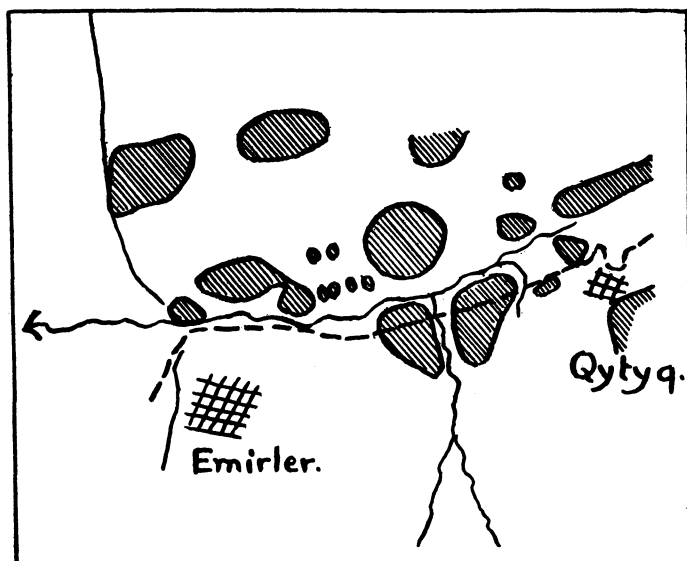


FIG. 7.—Sketch of a small area near Emirler, just north of Boghaz Köi, showing the relation between limestone and serpentine usual in that district. The hatched areas are limestone; the remainder is probably mostly or entirely serpentine, but largely covered up.

as shown on the map, it seems to disappear within a short distance under the serpentines. But it probably extends farther to the southeast and east, through the area left white on the map.

North-northeast of Boghaz Köi, the mixture of serpentine and marble continues half-way to Eyük, the serpentine dominating for the southern half and disappearing in the northern half. About at the point where the serpentine ceases to appear in any quantity there are several outcrops of denser igneous rocks. The space immediately south of Eyük is occupied by fine-grained Neocene limestones, containing plant remains in poor condition. A little

farther west, and more directly north of Boghaz Köi, there is no sign of the limestone or serpentine, but the Eocene (?) rocks which extend west to Yaghly take their place.

THE YUZGAD COMPLEX

Five or six miles south of Boghaz Köi the serpentines and limestones again make way for the rocks of Eocene facies, but now they are much interrupted by igneous rocks in great variety. Our road, the new chaussée, ran at first southeast, over the divide. Then we entered the valley of a large stream which flows off to the southwest and is followed by the old chaussée. We went upstream (to the east) for a couple of miles along one of its tributaries, after coming down from the divide along another; and then we turned abruptly southeast to cross the very top of Kabak Tepé, the mountain just north of Yuzgad, by a very complex system of zigzags. From the height of land till we left the main valley to climb Kabak Tepé, and actually till we were fairly up on the slopes of Kabak Tepé, the supposed eocenes make up the mass of the rock. Southwest of the road about a mile south of the divide there could be seen a flat mesa which has been used for "cliff-dwellings." It is probably a tuff or soft trap like the beds so used elsewhere, and made a distinctly incongruous note among the other rocks of the district. In any case it is Neocene in date, and unconformable on the local bedrock. Northeast of the road in the same neighborhood there are several appearances of granite (probably more nearly of the date of the bedrock). At the point of forking of the old and new chaussées, where the road ceases to go south down one tributary and turns east up the other, there are a couple of trap dykes, both small, but perhaps outliers from more extensive intrusions to the north.

A couple of miles south of the valley of the tributary running from east to west the supposed eocenes either disappear or else change their character entirely under the influence of the many igneous rocks, which now become dominant. Of this district one can only say that it is a practically inextricable tangle. It is composed, among other rocks, of granites, dark traps, schists, fragments of Eocene beds (some containing fossils according to Tchi-

hatcheff), tuffs, and Neocene sandstones and conglomerates. Immediately about the town there are several outcrops of tuff.

Hamilton and Tchihatcheff report the same types as making the entire region west to near the Delidjé Yrmak, and northeast for an equal distance. To the southwest, however, after about ten miles they gradually give place to neocenes, which extend in the main to Hadji Bektash. Tchihatcheff discusses this complex with the dolerites.

Getchi Kalesi, the mountain to the east of Medjidié, in the northern part of the Malya Tchöl, is only the culminating point in a limestone range, cored with trap, which extends from west of Medjidié southeast for a dozen miles. The limestones at several points contain Eocene nummulites in quantity. At the point where the road traverses this series, south of Medjidié, the eocenes are not conspicuous, and the traps are locally interrupted, but behind the city, the traps stand up in a series of prominent and ragged hills. Even here I have a feeling that the igneous dyke is not entirely continuous. A little farther south, and on the other side of the path, the igneous rocks appear again in a couple of amorphous masses (as seen from a distance), the eocenes remaining inconspicuous, but Getchi Kalesi itself is of a somewhat different structure. The dyke here seems to be fairly continuous, and in general makes the crest of the ridge. Leaning against the west side of this is a long series of Eocene limestones, etc., all with dips of about 60° to the north. Apparently on the east side of the dyke the same facing occurs, and the very highest point of all is formed by one of these strata which is continuous across the top of the dyke. This very topmost point furnished one of my nummulite specimens, through the kindness of Mr. Wrench.

A little farther south the village of Mahmatly is situated in a very striking gorge, which marks the boundary between a lower and a higher level of the Malya Tchöl. On the steep sides of this gorge, as well as the escarpments that lead up to its mouth, the neocenes are interrupted, laying bare the substratum of the Tchöl, which is evidently of the same system as Getchi Kalesi mountain. Half a day's journey farther south there is a long hill a moderate distance west of the road, which again shows the

steeply dipping strata of the Eocene series. At one place *Nummulites lævigata* (Lutétien period of the Eocene) was picked up, but not *in situ*.

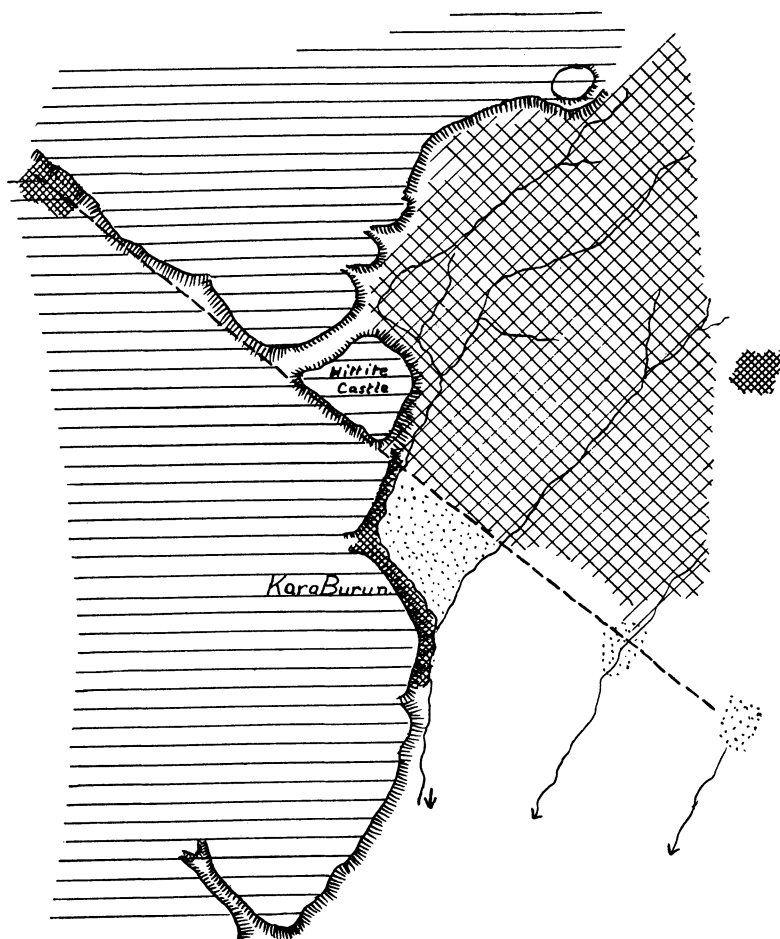


FIG. 8.—Kara Burun and immediate vicinity. The trap is indicated by horizontal lines, the granite by coarse cross-hatching. Gardens have been shown in stipple, indicating the position of springs.

There are also some smaller igneous outcrops in the neighborhood of Medjidié, which do not seem to belong to the Getchi Kalesi range, in particular a neck of very coarse porphyry some five miles northeast of that town and on the other side of the river.

The district between the Malya Tchöl and the Kyzyl Yrmak valley to the south is again apparently eocene in date, resembling closely in appearance the Haimané and the vicinity of Sungurlu. The very top of the divide south of Hadji Bektash showed no outcrops, but the pebbles brought down and the appearance of the distant hills would imply that it also had a volcanic core. It is a very much more insignificant ridge than Kiepert's map would suggest.

KARA BURUN

The village of Kara Burun is located on the east slope of a mesa capped with a sheet of hard black trap. This sheet disappears abruptly at the north end of the village against a steep bluff of much-rotted granite, which in its turn is capped with a second sheet of trap exactly similar to the first, but on a higher level. The lower level trap, like the upper, seems underlaid with granite.

East of the upper level, the granite is laid bare in several places, but east of the lower level there are no near outcrops. On the south boundary of the granite outcrop there is a line of springs marked by gardens and villages, of which the first is Kara Burun itself. The whole, with the line between the upper and the lower Kara Burun traps and the southern boundary of the Eocene deposits farther to the east, forms a line nearly parallel to the Kyzyl Yrmak river which I have interpreted as possibly a fault.

East of Kara Burun the Kyzyl Yrmak valley, as far at least as Avanos, is filled with a series of almost horizontally bedded neocenes, more or less tufaceous, which gradually rise as one goes east. They are cut off to the south by the valley of the river, and seem on the north to end abruptly against the eocenes. Farther to the east, as one approaches Avanos, the eocenes appear from below and the later deposits make only a narrow cornice against the bluff. Some of this series of beds are more or less water-worn conglomerates, while others are fine-grained tuffs of very even texture. The latter especially have been much used by the troglodytes for excavating houses, churches, and tombs.

South of the river one can see a great confusion of lava-sheets, the spaces between which are taken up by vast masses of tuff. Occasionally the tufaceous matter would become less noticeable,

and they would grade into the usual Neocene conglomerates. The trap-sheets hardly appear north of the river, except at Kara Burun.

Several miles west of Inje Su there is a perfectly flat plain, formed by the vesicular surface of one of the trap-sheets. Nearer to Inje Su itself a stream has cut a deep gorge in this bed, exposing the underlying tuff.

The district between Avanos and Inje Su is the famous troglodyte country, which also extends a long distance to the south, to the west of Mount Argæus. In the neighborhood of Ürgüb there had evidently been at one time a thick layer of fine homogeneous tuff, capped with a thin trap-sheet, which though harder than the tuff was itself easily weathered and cracked into blocks. Erosion has cut this whole district into a mass of cones of tuff, the higher ones of which are still capped with small blocks of trap. Between these higher ones there are a vast number of shorter cones, whose lava caps have fallen off, and which are fast being eroded away. When the cap falls off it sometimes finds new lodgment at a lower level, and becomes the nucleus of a new shorter cone. Hundreds of the cones have been used by the troglodytes for excavating houses, and many of these are still in use. Where the country is at a little higher level, at Ürgüb village, the country is not broken up into separate cones, but there is a large mass of tuff, crowned by a continuous sheet, and terminated to the north with a continuous cliff. The village was originally a system of troglodyte houses excavated in the face of this cliff, but most of the houses have added built façades in more recent times. It is still distinctly a troglodyte village nevertheless.

Beyond Inje Su notes were not taken, but the general character of the country does not change. Tchihatcheff spent considerable time in this district, and gives a long and interesting account of it in the section "trachytes" of his geology of Asia Minor.

THE LACUSTRINES

In this survey I have passed over several sections of the route with hardly a word. These are occupied by the characteristic Neocene (lacustrine) deposits which seem to cover nearly half the surface of Anatolia. They are in general horizontally bedded or

nearly so, sometimes fossiliferous—then generally Pliocene—often formed of the same materials as the eocenes of their district. Still more often they show a more or less characteristic appearance, and may usually be distinguished by their horizontal bedding.

In every place where they come in contact with the trachyte (andesite) deposits, they grade into their tuffs, and are evidently in a general way of the same period. This shows conspicuously at Yuzgad and along the Kyzyl Yrmak near Caesarea.

Here is a list of the places where I found deposits of this type to predominate:

The Sakaria valley near Aktash, and from there to Sivri Hissar.

The Sakaria valley from Sivri Hissar east to the river at Gordium.

The country east of Hammam Merkes and Giaour Kalesi.

The Kyzyl Yrmak valley from Yakshy Khan to Yaghly.

The region about Eyük.

The region beginning just south of Yuzgad and extending the entire length of the Malya Tchöl almost to Hadji Bektash.

BIBLIOGRAPHY

Congrès géologique internationale. *Compte rendu de la IX^e session*, Vienne, 1903. This contains two important papers on the Bibliography of Asia Minor, so complete that it seems unnecessary to give a detailed bibliography here. These are:

TOULA, FRANZ. *Der gegenwärtige Stand der geologischen Erforschung der Balkan-Halbinsel und des Orients*, p. 175; followed by—

TOULA, FRANZ. *Übersicht über die geologische Literatur der Balkanhalbinsel mit Morea, des Archipels mit Creta und Cypern, der Halbinsel Anatolien, Syrien und Palästinas*, pp. 185 to 330. This is a bibliography of over 1,300 titles, arranged chronologically.

VON BUKOWSKI. GEJZA: *Neuere Fortschritte in der Kenntnis der Stratigraphie von Kleinasien*. *Loc. cit.*, p. 393. A bibliography arranged by authors.

HAMILTON, WILLIAM JOHN. *Researches in Asia Minor*. 2 vols. London, 1842.

A book of travels with frequent geological notes. The geological part, as well as that of the other older authors, has been summarized by Tchihatcheff, and harmonized with his own observations.

TCHIHATCHEFF, PAUL DE. *Asie Mineure*. Paris, 1866 to 1869. *Paléontologie* by A. d'Archiac, P. Fischer, and E. de Verneuil, in one vol., with atlas.

———. *Asie Mineure. Géologie*, in 3 vols., with a geological map of Asia Minor, and one of the Bosphorus. The classic.

———. *Asie Mineure*. There are numerous other papers by Tchihatcheff, for which one may consult the bibliographies cited above.

- SCHAFER, F. Cilicia. In Petermanns Mittheilungen, Ergänzungsheft 141, 1903. It contains a geological map of Cilicia and the neighboring district, which adjoins the route of our studies on the south.
- LAPPARENT, A. DE. *Traité de géologie*. Ve. édition, 1906. Summarizes the stratigraphical knowledge of Asia Minor along with the rest of the world.
- LEONHARD, R. Geologische Skizze des galatischen Andesitgebiets nördlich von Angora. *Neues Jahrbuch für Mineralogie*, etc. Beilageband XVI, 99 to 109, with a sketch map.
- D'ARCHIAC, A AND J. HAIME. Description des animaux fossiles du groupe nummulitique de l'Inde, précédée d'un résumé géologique et d'une monographie des nummulites. Paris, 1853. A useful reference book on the nummulites.
- WILSON, SIR CHARLES. Handbook for travelers in Asia Minor, Transcaucasia, Persia, etc. (Murray's Handbook). The most convenient book for geographic information.
- KIEPERT, RICHARD. Karte von Kleinasien. 1:400,000. Berlin, published in sheets. The standard map of the country.