THE DIFFERENT CONCEPTS OF THE GENESIS OF ALPINE-TYPE EMPLACED ULTRABASIC ROCKS AND THEIR IMPLICATIONS ON CHROMITE PROSPECTION *

G. van der KAADEN

Mineral Research and Exploration Institute of Turkey

INTRODUCTION

The genesis of ultrabasic rocks of the alpine-type and the chromite deposits associated with them, once thought to be relatively simple, has become increasingly more difficult to explain as our knowledge of these rocks and deposits increased.

The world literature on this subject accumulates rapidly and especially in the last decade important contributions from geological point have been forwarded among others by Bailey and McCallien (1953), Borchert (1960, 1961), Brunn (1954, 1960), Dubertret (1955), Helke (1961, 1962), Hiessleitner (1951, 1952, 1957), v.d. Kaaden (1959, 1960),Kündig (1956), Milovanovic and Karamata (1960), Ovchinikov and Harris (1960), Peive (1960), Petrascheck (1957), de Roever (1957, 1961), Ross, Forster and Meyers (1954), Rost (1959, 1961), Stoll (1957), Schmidt (1954), Thayer (1960a, *b),* de Wijkerslooth (1954), to mention only a few.

New handbooks by Schneiderhohn (1958) and Donath (1962) give a lot of compressed knowledge.

From geochemical, petrological and geophysical sources, an increasing wealth of information was collected in recent years.

In this respect the important paper by Bowen and Tuttle (1949) on the system $MgO-Al_2O_3-SiO_2-H_2O$ should be mentioned.

In general, however, detailed mappings of chromite areas in a modern sense are relatively scarce. They should give a better understanding and a basis for discussion. Such modern maps are for instance published by the U.S. Geological Survey on chromite areas in Cuba and California, and also the area of Başören, near Eskişehir (Turkey), mapped by Schmidt (1954) should be mentioned in this respect.

They could be used as a standard for mapping in other chromite districts. The wide range of opinions put forward in the above-mentioned papers can be partly explained by the fact that certain authors studied the ultrabasic rocks in their geological surroundings, but did not study textural relations of ultrabasic rocks and chromite deposits, which are so important for a proper understanding of the problem. Other authors studied chromite deposits in certain details but did not pay enough attention to the surrounding rocks and their special features.

Quoting v. Bemmelen (1961) : «The subjective element in geological studies accounts for two characteristic types that can be distinguished among geologists. One considering geology as a creative art, the other regarding geology as an exact science» and «much of the practise of geology is a visionary art indeed, since a creative, but scientifically controlled, imagination is required.»

The geologist is forced to test the validity of the greatest possible number of presuppositions, but is at a disadvantage where it is difficult to. verify the observations of other geologists, because of inaccessibility of the area or of now buried outcrops.

Before a sound interpretation on the genesis of alpine-type emplaced ultrabasic rocks and their chromite deposits is reached, many detailed supplementary investigations and observations, combined with information collected by geophysicists, petrologists, geochemists, should be done.

TECTONIC-GEOLOGICAL CONSIDERATIONS

Hess (1939, p. 263) already pointed out that typical serpentinized peridotites, which occur as narrow belts paralleling island arcs, mountain systems, or eroded former mountain systems, are limited entirely to such strongly deformed belts and do not occur elsewhere. Rost (1959) calls attention to the fact that the ultrabasic complexes along the alpine folded European mountain system are devoid of chromite deposits in its western part, such as Wallis, Bernina, Zillertaler Alps, Hohe Tauern, and that starting from Kraubauth in Styria chromite deposits can be followed towards SE over the Balkan to Asia Minor. *Independent of the age* of the orogenesis during which the ultrabasic rocks are emplaced, the eastern part of Europe, Asia Minor, Schlesien and the Urals have ultrabasic rocks associated with chromite deposits.

This seems in favor of original compositional differences of large sub-crustal areas of the earth, from which these ultrabasic rocks generated and is difficult to explain by different levels of magma-chambers with their magmatic differentiation products.

Thayer (1960) stressed that knowledge of the textures and structures characteristic of stratiform complexes, such as Bushveld and Still water, are highly important for appraisal of the various theories of origin, as original crystallization relations are best preserved in them. He listed the fundamental differences between alpine - emplaced ultrabasic rocks on one side and stratiform complexes on the other side. These differences are confirmed by Jackson (1961) in his paper on the Stillwater complex.

There is hardly any doubt now that belts, like the ultrabasic belts that cross Turkey, are associated with abyssal fractures [Peive (1960), Mouratov (1960), Khain (1960), Borchert (1961) and others].

Abyssal parallel fractures probably play an important role in the tectonic development of Turkey. Along them chains of ultrabasic rocks extend, following the borders of the geosynclinal foredeeps.

They separate stable masses such as pre-Paleozoic and Paleozoic folded basements from highly deformed units and branches.

According to Peive (1960) this magmatism is associated with a category of abyssal fractures which are apparently penetrating into the mantle. A periodic rejuvenation of these fractures, with a certain shifting in the upper parts, is indicated by the different age of emplacement of ultrabasic rocks in Turkey.

The northern, more or less E-W running zone, Bursa-Eskişehir-Ankara - Tokat-Erzincan, is most probably Paleozoic emplaced. The southern zone seems emplaced in Mesozoic time or rejuvenated in Mesozoic time, but independent of age of emplacement, or original depth of final emplacement, there are no fundamental differences in petrology of chromite deposits and their textures in both zones.

Processes of subsidence and uplifting of conjugated parts of the crust are displayed throughout the entire geological history of Turkey. At the beginning of the Mesozoic a levelled out area with folded Paleozoic, including ultrabasic rocks and spilitic flows and diabases, was formed and dissected into gently inclined depressions and uplifts. Then a recurrence to its original state started at the beginning of Lower Cretaceous. Especially during the Upper Cretaceous, dissection of the area into depressions with residual uplifts took place. All these structures started on a folded Paleozoic basement as a result of the development along the fracture systems.

Older massifs are part of this basement, which have not been involved in these movements.

The areas surrounding them were dissected by vertical and horizontal movements, emplacement of ultrabasic rocks along the abyssal fractures and spilitic-keratophyric lavas along the same fractures, but mostly separated in time from the ultrabasic rocks and often also in space and followed by younger folding.

Mostly the connection with the roots of the «intrusions» has been disrupted by the younger folding and gliding.

Continental slopes and edges are prone to develop into steep flexures as a continuation of the abyssal fractures.

Khain (1960) stressed the fact that nearly all alpine geosynclines of Europe originated within marginal parts of a platform at the end of the Hercynian.

Peive (1960) thinks that the formation of geosynclinal furrows and geoanticlinal ridges is associated with more surficial horizontal displacements of crustal blocks, their lateral thrusts and overthrusts along abyssal fractures, but related to magmatic masses shifting in the abyssal parts of the earth. Abyssal fractures cutting the upper crust determine the direction of these displacements. In this respect, the position of the Mohorovic discontinuity (M.D.) is of importance. Recent results from geophysical sources are summarized by Bederke (1957). This M.D. probably marks the boundary *of* the peridotitic substratum. This substratum is probably layered. It is only 6 km below the bottom of the Pacific Ocean and 15 km below the bottom of the Atlantic Ocean. Under the continents it shifts to a depth of perhaps 30-40 km. The youngi mountain chains of North America are characterized by a rather shallow depth, of the M.D.

According to Russian information (Khain, 1960), data have been obtained proving an abrupt change in depth of the M.D. across abyssal faults. This would impose no improbable mechanism for bringing peridotitic material to the surface, by relief of pressure and rise of temperature, perhaps released by basaltic material rising from below the M.D., transferring the peridotites from the elastico-viscous field to the field of flow.

The basaltic volcanism, i.e. spilites and keratophyres and diabases, has probably its origin in regions below the M.D., either by squeezing out of interstitial magma between the crystals of the ultramafic mantle rocks or, as suggested by de Roever (1961), as a by-product of the decay of Mg- and Si-rich high-pressure spinel in the rising column of a convection current, where a considerable increase of the temperature is to be expected. Hurlay (1951) postulates that some basalts are concentrates from partial fusion at depths of at least several hundred km within the mantle.

There is growing recognition by geophysicists of the great importance of phase-transformation processes in the matter of- the mantle with a formation of more compact modifications under the influence of great pressure dominating at these depths.

Further the investigations of geological formations of the Urals and pre-Urals on their absolute age by Ovchinikov and Harris (1960) showed that the development of intrusive complexes, particularly those with a complex structure and deep differentiation, lasted apparently many ten millions of years.

THE DIFFERENT CONCEPTS

The following concepts of the genesis of alpine-type emplaced ultrabasic rocks, and the enclosed chromite deposits are discussed. All of them have supporters.

1. *Emplacement of solid peridotitic material from the peridotitic substratum.* The chromite deposits are brought up with them in a crystalline state. The observed layering, foliation and lineations are explained as inherited from the substratum as a metamorphic texture. Chromite deposits were already deformed in depth by metamorphic processes and flowage. They were torn apart by differential movements and affected by metamorphic readjustment in the pre-serpentine state (Rost, 1959) and of course by post-serpentine deformation during their emplacement.

Supporters of this concept are de Roever (1957, 1961), Rost (1959).

2. *Emplacement of reactivated peridotitic material from the peridotitic substratum in the form of crystal mushes.* The chromite deposits were brought up with them in a solid state. Limited resorption and reactions took place in chromite in the mush-like state of the silicates with a fluid phase, and also metamorphic readjustment in the pre-serpentine state. The chromite deposits were torn apart and stretched during their emplacement by flowage of the crystal mush. Also xenolithic

blocks of gabbroic to pyroxenitic composition were involved in these movements. Primary textures were modified to flow textures.

Supporters of this concept are Bowen and Tuttle (1949), Thayer (1942, 1960), Flint and de Albaer and Guild (1948), Wells, Smith, Rynearsen, Livermore (1949), Stoll (1958), Philips (1938), Ross, Forster, Meyers (1954).

3. *Emplacement of peridotitic magma.* The larger concentrations of chromite were formed in depth. After emplacement of the magma and the chromite concentrations therein, new crystallization and concentration of chromite from the crystallizing magma were only possible on a very limited scale because of the high viscosity of the crystallizing magma. Resorption of older chromite concentrations was possible on a limited scale. Metamorphic readjustments were possible (Wijkerslooth, 1942). Flowage of magma disrupted already formed chromite concentration. Later post-crystalline tectonic movements disrupted them still more.

Supporters of this concept are Hiessleitner (1951, 1952), de Wijkerslooth (1954), Hess (1955), Wilkinson (1953), Noble and Taylor (1960), Schmidt (1954).

4. *Intrusion or even extrusion of basaltic material originating below the M.D. and differentiated in laccolithic bodies.* The chromite deposits were formed by gravitational-fractional crystallization in place. They have the same origin as the layered complexes. The eventual effusive character of «ophiolitic» magmas is supported by Bailey and McCallien (1953), Kündig (1954), Brunn (1954, 1960), Dubertret (1955), who did not study the chromite deposits.

It is also supported by Petrascheck (1959) and Borchert (1960, 1961), who studied chromite deposits in detail.

Brunn states : «The constant association, in the important ophiolitic masses of northwestern Greece, of coarse-grained rocks (peridotite-gabbros) with doleritic, fine-grained and pyroclastic rocks, the lack of volcanic apparatus and of metamorphic envelope, i.e. the outcropping in great masses on the sea floor, of a mean ophiolitic magma (non-peridotitic) later differentiated under a cover of doleritic and associated material and under reduced pressure.»

For Turkey «extrusive» character is supported by Dubertret for the Hatay - İskenderun region and for the Guleman-Soridağ region by Borchert (1960, 1961), Kündig (1954), Petrascheck (1959).

5. *Intrusion of basaltic magma, forming stratiform complexes in depth.* In a much later geological epoch they were involved in Alpine-tectonic movements. This concept is supported by Helke (for the Soridağ-Guleman region) and in general also by Donath (1962).

It is a variant of the fourth concept, with the difference that the crystallization was slow because of slow cooling conditions. Forster and Grafenauer doubt whether it is possible at all that the basaltic magma might be considered as the mother magma of peridotitic rocks.

6. *Ultrabasic complexes were formed as the effect of a local basification and rheomorphic mobilization of rocks in the basement complex of a rising front of acidification and anatexis.*

This theory is supported by v. Bernmelen (1960, pp. 107-109) and, in a somewhat modified form, by Perrin and Roubault, Avias for New Caledonia, and van Biljou for the Bushveld complex, v. Bemmelen thinks it also possible that tensional rifting in the geosynclinal area promoted the ascent of basic to ultra-basic magma from deeper levels in the substratum.

Critical evaluation

Principally there is not much difference in the *first three concepts.* Only that the observed crystalline deformations of ultrabasic rocks and chromite deposits in the pre-serpentine stage occurred already in depth if we accept the first concept. *The second and third concepts* differ only in the mobility of the silicate melt. In the *second concept* this is thought to be a mobile mainly olivine crystal mush, in the *third concept* it is to be a viscous magma.- Both concepts agree that most of the chromite concentrations were already formed in depth and taken up in the rising mush or magma column.

The time of the ultimate differentiation of the chromite deposits cannot be fixed. The geological age of the ultrabasic rocks is that of their first emplacement.

A limited formation of new chromite deposits seems possible if we accept the third concept. Both were subjected to metamorphic readjustments prior to the serpentinization (Rost, 1950).

All three concepts explain more or less the distinct shear planes observed in all kinds of Turkish chromite ores (Krause, 1958) and the frequently observed elongated forms of nodular ores, the agglomeration of chromite ores in pre - serpentine stage, the lineations, foliations observed and the plastic deformation of olivine (Chudoba and Frechen, 1950).

The first and second concepts, however, explain better the observed world-wide phenomenon that the metamorphizing effect of even large bodies of peridotites of the alpine-type is astonishingly slight. There is sometimes only a metamorphism corresponding to the low-temperature facies within the meta-morphic range.

The Stillwater layered intrusive on the other hand is surrounded by an aureole of high-temperature hornfelses.

This lack of contact metamorphism around the alpine-emplaced ultrabasic rocks seems incompatible with any hypothesis involving intrusion of largely liquid magma.

Also, rapid cooling cannot explain this phenomenon, because petrological evidence shows overwhelmingly that cooling conditions were slow, as is expressed by the grain size of chromite and the silicates, which is in general much coarser than that of the layered complexes which show high-temperature contact meta-morphism. In Soridağ grains of olivine up to five cm were seen by the author and the coarse grain size of the Guleman deposit is well known (de Wijkerslooth, 1947).

Also, the undifferentiated rapidly cooled rocks, which are so characteristic in the Stillwater complex in the endogenetic contact zone, are lacking in the footwalls of the ultrabasic rocks of the alpine type. Donath (1962, p. 46) thinks, for instance, that the chromite deposits of the Balkans and Turkey are principally of the same origin as those of the Bushveld, but explains the differences by smaller volumes of the complexes, compared with those of the Bushveld, and by more rapid cooling of the former. This explanation seems not very likely taking into account the previous considerations.

The second concept explains the lack of real contact metamorphism if it is assumed that the fluid constituted only a few percent. The energy set free by crystallization would then be very small and in that case the borders of the emplaced mass would be rapidly cooled into the temperature-stability range of serpentine and any significant inflow of water from the country rock would inhibit or prevent contact metamorphism (Thayer, 1960).

Not only chromite concentrations were brought up in solid conditions, but also blocks of gabbroic composition, according to the first and second concepts. Accepting the second concept, a certain adjustment and recrystallization seem possible of enclosed gabbroic rocks and also corrosion of chromite and the formation of chromium hornblende, uvarovite and kaemmererite in the pre-serpentine stage of the ultrabasic rocks.

The often observed fact of blocks of amphibolites along the borders of the emplaced massif or inclusions of amphibolites in the ultrabasic rocks, which are not or only slightly readjusted, is best explained by the second concept.

Stoll (1958, p. 444) summarizes as follows: «What may have been the exact physical-chemical state of the mass, the geological and petrological evidence appears to show that the peridotite possessed mass mobility, moderate or high temperature, tenuousness sufficient to penetrate microscopic openings and a chemically reactive or corrosive effect on chromite.»

All three concepts, however, explain more or less satisfactorily the phenomena of foliation, layering, lineation, flow structures and deformations in the pre-serpentine stage of chromite deposits and ultrabasic rocks and their gabbroic inclusions.

Although such phenomena are described among others by de Wijkerslooth (1942, 1947), Hiessleitner (1951, 1952), Schmidt (1954), Thayer (1942, 1960), Helke (1961), Henckmann (1942), Petrascheck (1957), it was Thayer (1960) who stressed the genetic importance.

Mapping according to these principles by Wells, Smith, Rynearson, Livermore (1949) in California shows the great importance of such textures for the evaluation of chromite deposits.

The fourth and fifth concepts, differentiation of a basaltic magma that may even be extrusive, in laccolithic bodies, either in depth or at the bottom of the sea floor, with no cover of sedimentary formations or of a relatively thin cover of unconsolidated sediments, with the formation of chromite ore bodies and coarse-grained ultrabasic rocks, seems highly unorthodox in the case of extrusion, but also the fifth concept—differentiation in depth of a basaltic magma, as supported by Helke for Soridağ-Guleman district,— is difficult to explain.

The differences between the stratiform, lopolithic complexes, such as Stillwater and Bushveld on one hand, and Soridağ-Guleman on the other hand, arc so characteristic that a different genesis is almost certain. These two concepts do not satisfactorily explain:

1. If the original magma was basaltic and differentiated in place, a much larger portion of acidic magma should be expected in a stratiform position on top of the ultrabasic differentiate, as is obseryed in Stillwater and Bushveld. This point is also stressed by Hess. It must be kept in mind that the emplacement of «ophiolitic magma» took place during the first quiet subsidence along the fractures, and before the folding started. For instance, the large folding with overthrusts in the Guleman-Hekimhan regions is Oligocene to Miocene. Already Upper-Cretaceous conglomerates are on top of peridotites in both regions with reworked peridotitic rocks. For this reason Helke postulated a Paleozoic or even older age for these ultrabasic rocks and explains them as remnants of a lopolithic body. However, no acidic rocks which should have been removed by erosion from the upper section of the lopolith are found, either in stratiform remnants or in conglomerates.

2. Also the pre-serpentine textural features of the chromite ore bodies in Soridağ are difficult to explain this way. Lineation features were observed by the author on a joint trip to Soridağ with Dr. Thayer, indicating that the chromite ore bodies are French loaf-shaped and are not stratiform layers disrupted by post-crystalline tectonic movements. The same was observed by Schmidt (1954) at Başören.

3. In the case of extrusion of basaltic undifferentiated magma at the sea bottom, or under only a thin cover of unconsolidated sediments, with the formation of coarse-grained ultrabasic rocks at the bottom with a cover of doleritic, spilitic-keratophyric material at the top, it should be remarked that the cooling of such a magma would be much too quick to allow such a differentiation at all. As remarked, such differentiation takes probably tens of millions of years.

According to Levering (1955), decline of temperature has the largest influence on increase of the viscosity of a magma. A fractional crystallization-differentiation is impossible if a magma gives its heat off rapidly. This is certainly the case if we assume extrusion of basaltic magma in water-soaked geosynclinal environment, even if there is a certain cover of lavas on top of them.

A drop of temperature of a tholeitic magma of 100°C increases the viscosity forty times. The author is certain that another satisfactory explanation for the so-called transitions of lavas to ultrabasic rocks will be found, if said areas are reinvestigated.

But even assuming this to be theoretically possible, it does not explain the textural features of the chromite ore bodies of the pre-serpentine stage. There is no evidence of pre-serpentine continuous layers of chromite.

As already pointed out before, a sheet of undifferentiated basaltic material should be found around the ultrabasic mass, also at its base as a rapidly cooled layer. In contrast to the Bushveld and Stillwater lopoliths, this has never been observed here.

The sixth concept does not explain the concentration of chromite and will not be discussed further.

THE CONCEPTS TESTED ON THE ULTRABASIC COMPLEX OF SORİDAĞ — EASTERN TURKEY AND THEIR APPLICATIONS ON CHROMITE PROSPECTION

The example of Soridağ is chosen, because it has been studied or visited by several members of this congress and will therefore give a better basis for discussion.

For the members who did not visit this important chromite district, a short summary of the geological setting follows (mainly after Helke, 1961; Tolun, 1954; de Wijkerslooth, 1947).

The oldest non-igneous rocks of the district arc metamorphic rocks, such as amphibolites, quartz-chlorite schists, gneisses and marbles of Paleozoic or older age and deformed in a pre-Mesozoic period. They are found in the footwall of the ultrabasic rocks and exposed on the eastern side. The ultrabasic rocks of the Soridağ district are relatively unserpentinized.

The western parts have a more gabbroic composition, the eastern part with the chromite deposits a peridotitic, mostly harzburgitic composition, with dunitic material around the deposits.

The deposits resemble somewhat the Cuban deposits with their gabbroic rocks in the upper zone, or the deposits of Cyprus.

No contact "metamorphism is observed in the footwall of the complex. During, the Maestrichtian a basal conglomerate was formed on top of the gabbroic rocks, with coarse reworked gabbroic material grading locally into an arenaceous sediment (Helke, 1962).

Such a conglomerate could also be observed in the Hekimhan area north of Malatya, where it is located below Rudistic limestones of Upper Cretaceous age, and is also mentioned by Helke (1962) and Romieux (1911) in the environment of Ergani Maden in the west. There the conglomerates are on top of peridotitic rocks.

During the subsidence the foredeep was filled with pelitic sediments, radiolarian cherts, limestones and marls. According to Helke (1961), the oldest fossils that have been found indicate Turonian age.

Contemporaneously with the sedimentation, submarine volcanic activity created large flows belonging to the spilitic-keratophyric suite and their pyroclastics, including intrusive diabases.

In many parts the volcanics are more abundant than the sediments. Sedimentation and volcanic activity ceased at the beginning of the Oligocene. The effusive masses, advancing on the sea- bottom by gravitational forces or effusive push mixed with blocks of the sediments, probably took up also blocks • or slices of older peridotitic material, creating a melange.

This picture became more chaotic through alpine folding which started probably at the end of the Oligocene. In post-Aquitanian times the folding was intensified and overthrusting was the main tectonic feature. The geosynclinal series, including parts of the ultrabasic rocks and their cover of Upper Cretaceous Lower Eocene sediments, were overthrusted along northerly dipping planes in a southerly direction upon younger sediments. This was described by de Wijkerslooth (1947) for the Guleman-Kündikan area and by Helke (1955) for the Kundikan-Guleman-Kelhasi area.

Also diapirism of slices and sheets of serpentinized ultrabasics between the geosynclinal series is described by Helke (1962).

Milovanovic and Karamata (1960) described such phenomena in detail from Yugoslavia, stressing the fact that this may lead to agglomeration of ultrabasic rocks, enveloping fragments of the surrounding rock formations such as limestones, radiolarian cherts.

This explains the boulders observed in the Guleman area consisting of fragments of serpentine and limestones. They are considered by Petrascheck (1959) as volcanic agglomerates of the ophiolitic magma, which seems very unlikely considering the previously mentioned arguments.

The difference in age of the emplacement of the ultrabasic rocks on one side and the submarine flows and their pyroclastics on the bther side is clearly demonstrated in the case of the Soridağ-Guleman area. The ultrabasic rocks were already subjected to erosion before the onset of submarine volcanic activity.

This is also demonstrated by Petrascheck (1959) for the island of Euboea (Greece) and for Cuba by Thayer (1942) and Flint, Albear, Guild (1948). This makes the origin of ultrabasic rocks with their chromite deposits and the spilitic-keratophyres with manganese ores, ferrugineous manganese ores and copper-pyrite ores, *out of one basaltic magma,* differentiating under a cap rock of quickly cooled lavas and diabases very unlikely, *although they are not divided in space.*

Also, the extreme coarseness of chromite ore, as observed in Guleman, and of silicates, as observed near the deposit Uzun Damar in the Soridağ, is more in favor of extremely slow cooling conditions. In this respect, the author agrees with Helke (1961, 1962) that there is fundamental difference in genesis between the chromite-bearing ultrabasic rocks and the rocks of the spilitic-keratophyric suite.

The area of Soridağ is relatively little serpentinized, as already mentioned, but it is affected by post-crystalline faulting. The longest outcrop or, better, series of outcrops is called Uzun Damar. It can be traced for 1200 meters. The thickness along this outcrop varies from approximately 5.5 meters to almost zero. The overall inclination is 40°W. The other seams or lenses are shorter and situated in the hanging wall with large barren intervals.

In all the seams or lenses there has been a reaction between chromite and the silicates, creating chromium hornblende. This might have happened in the metamorphic stage of the deposit, as described by de Wijkerslooth (1943) and Rost (1959).

Helke states that in its present state of exploration it has by no means been established whether its four chromite seams were produced by a repetition of the magmatic chromite crystallization, or whether this is a case of tectonic repetition.

According to *the fifth concept,* laccolithic layered complex supported by Helke, the original position of the chromite layer or layers must have been sub - horizontal and must have considerable planar extension. They were later tilted to their present position.

The much coarser-grained ore of Guleman are parts of a deeper layer which was subjected to much stronger posterior tectonic fragmentation.

The fourth concept, strongly supported by Borchert (1960-1961), implicates that the chromite concentrations resulted from settling of chromite crystals during the intrusion of a basaltic magma at relatively shallow depth. The steeply dipping ore bodies are considered as being differentiated in this position. The original steep attitude would facilitate massive ore concentrations in the lower parts of the layers. Borchert thinks that the ore bodies represent different layers and that the layering was the result of crystal settling along certain, sometimes steeply dipping planes.

Ore bodies of the type of Guleman would be expected down dip along such steeply dipping planes.

It should be kept in mind, however, that the viscosity of melts increases very rapidly at the onset of crystallization and that gravitational settling is therefore most likely during the earliest stages of crystallization, unless it is aided by convection or other currents in the magma (Hess, 1955; Jackson, 1961).

For this and the reasons mentioned previously, the process as described by Borchert is difficult to imagine.

In this respect it is worthwhile to mention that Petrascheck (1957) observed in Soridağ planar-banded ore bodies with a pronounced elongation, either in the direction of the strike of the layering or in the direction of the dip. This observation, in somewhat different form, could be confirmed by Thayer and the author during a joint visit to the Soridağ district in 1962. Thayer demonstrated that the elongation was in the direction of the lineation, situated in the plane of layering and making mostly a low-dip angle with the strike direction of the layering.

Also the fourth and fifth concepts do not explain the lack of cryptic layering so typical for laccolithic bodies.

It was also observed that real euhedral crystals of chromite in the Soridağ ores, as mentioned by Helke (1962) as being the rule, are extremely scarce or absent. We might better speak of grains and fragments. By closer observation this seems to be the rule in ultrabasic rocks of the alpine-type, as was shown by Hiessleitner (1957), Murdock, McCarthy (1942), de Wijkerslooth (1942) from deposits in Cyprus, Hatay (Turkey), North Carolina (U.S.A.). Thayer (1960) also stressed this phenomenon.

The two first concepts, and to a certain extent also *the* third, imply that the present attitude of deposits is not a valid criterion of any single mode of origin, as is implied by Borchert (1960) and to a certain extent by Helke (1962).

Also Petrascheck (1957) explains the steeply-dipping planar-banded ore bodies of the Ormiglia type in a different .way, by assuming flow-textures in steeply inclined or vertical rising, already differentiated magma.

These three concepts imply that nothing definite is known about the possible size, shape, abundance of the primary chromite concentrations in depth.

Whatever their original shape, the aggregations would tend to be pulled out parallel to the lineation, and mostly parallel to the plane of foliation, forming pencil to ruler-like ore bodies in the planes of foliation.

Only the third concept implies a certain crystallization of chromite after emplacement, but, because of the viscosity of the melt, this would scarcely lead to economic concentrations, but certain reaction with melt and chromite ore seems possible.

Of the five concepts the fourth and fifth are the most optimistic in respect to ore reserves of the district, because they presuppose continuous layers of chromite of considerable lateral extension.

It must be kept in mind that as chromite is a primary mineral of the ultrabasic rocks, the structures of the ore deposits are part of the primary structures of the ultrabasic rocks and in fact constitute the largest part of the internal structures that can be detected in the field in these rocks of simple mineralogy.

The structures of the ultramafic intrusions are of primary importance in the search for ore and this should be combined by small-scale regional mapping and large-scale detailed studies of the ore bodies. Mostly the prominent jointing is parallel to the layering and natural outcrops are apt to give too favorable impressions of tonnage and grade.

The situation is confused by failure to discriminate between different kinds of layering and by attributing layering to crystal settling. The author is in favor of one of the three first concepts and mostly of the second concept.

He hopes that this paper will give a basis for discussion on this highly interesting and complicated problem.

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