GEOLOGY OF THE ULTRA-BASIC ROCKS AND CHROMITE DEPOSITS OF SILINKOLOMON, INNER MONGOLIA

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The ultra-basic rocks of Silinkolomon, Inner Mongolia, are widely distributed in a NEE-SWW direction in an anticlinorium, which is composed of Silurian, Devonian and Permo-Carboniferous volcano-sedimentary rocks originally deposited in a geosyncline. The western margin of our present investigation is the Chining-Erhlien Railway Line, and the eastern margin just east to the Dabusu-Nor basin. From west to the east it constitutes a long but comparatively narrow area of about 450 Km. long with a width of about 30 Km. From this area westernly the anticlinorium runs probably in an east-west line along the line of the People's Republic of Mongolia and our country, and then NWW to the Mongolian Altai, and from this area easternly the anticlinorium runs slightly by north across the Great Khingan to the Tsitsihar region. It forms an arch with an apex pointing to the south. Upon this point of view, the ultra-basic rocks may still continue along the main tectonic line to the west and east distantly.

Under a long time of erosion and uplifting, the ancient faulted and folded beds and intrusives together with the Mesozoic beds formed the upland and the floor rock of the newer beds of the Mongolian plateau. The wide prevailing overlaying beds of Mesozoic and Cenozoic Ages, especially the latter, make it difficult to study the older floor rocks satisfactorily. By the help of geophysists, the main areas of ultra basic rocks have been determined. From west to east, the areas of distribution of these intrusives are Satuga-Sum, Malai-Sum, Hanbei-Sum and Chaokungder to Chungkengola separately.

In the Satuga-Sum area accompanied with area of Ardenkoli-Sum, both of which not far from the Chining-Erhlien Railway Line the rocks are all in the form of dikes with their long axes along the direction of Palaeozoic beds of metamorphosed andesitic and rhyolitic volcanisms and the slaty and limy sediments. All of these beds are strongly folded and faulted, striking in a principal direction of N 70° E with dips of high angles. The width of the dikes varies from several meters to one hundred meters, and the length is generally ten to thirty times to the width. The original peridotitic rocks have been altered to serpentine rocks and silicified strongly by more later weathering. Later congenetic dikes discovered are much rare as compared with the ultrabasic dikes. They are dikes of diorite, hornblende diorite porphyry and other more acidic rocks. Granite is in a form of stock and directly in contact with Permo-Carboniferous beds as well as the other intrusives do.

East to the Satuga-Sum area, over a wide depression of about two hundred kilometers, it is the Malai-Sum area, where the Palaeozoic beds and intrusives form an upland thinly covered with recent sediments. East to the old temple, the so-called Malai-Sum, there lay the outcrops of peridotitic rocks, which form the floor rock of an open valley. The smoothing rolling hills, lying to the north and south of the temple, are constituted by the ancient metamorphosed rhyolitic and andesitic volcanic rocks, and the sandy conglomerate beds. The ultra-basic rock body is much like a dike striking NEE, with a high angle dip to the south which is much alike to its older surrounding beds in structural features. Metamorphosed andesite and basalt are usually in a form of roof-pendant or xenolith occurred as an elevated block in the surrounding peridotic rocks, and much of these blocks arranged in a NEE direction. On the northwestern part of the ancient volcanos and intrusives, Mesozoic rhyolitic lava flows covered the ancient erosional surface. The peridotitic rocks as seen on the outcrops were strongly silisified and carbonatized by later weathering, and it is the present erosional actions that the fresh portion of the rocks are brought in view. The rocks mainly belong to dunite and peridotite, the former has been altered to schistosed serpentine and the latter changed to bastite serpentine both occur as ellipzoid bodies of varions size and cognate xenolith masses in the dunite rock. Chromite ore occurs as in tiny and irregular shaped masses with their longer axis parallel to the schistosity of the embodied schistosed serpentine or to the main tectonic line of this region.

The third area is the Hanbei Sum area in which the ultra-basic rocks have been revealed. This area is covered both by the Tertiary sediments, the even later basalt and by the recent eolian sands. The widespread basaltc lava flow forms the much flat but slightly rolling hills. The underlying ancient beds as seen in the hillside are the Palaeozoic metamorphosed beds accompanied with ultra-basic rocks.

The eastern area of our investigation is the more important area which consists of the areas of Chaokungder, Hugola, Bainola and Chungkengola, and further east to Usnahi, both lying south of the well-known Dabusu-Nor. The geological and geophysical works tell us that the ultra-basic rocks are distributed in three zones. The inner zone, or the northern zone, is a long and narrow zone which runs from Siaobaliang westerly to the Dabusu-Nor basin and covered by the Cenozoic beds, and not so far south-west to the Dabusu-Nor (salt lake) proper it turns to adirection of S 35° W, passing through Hugola to the Aoyaotgol, north of Chaokungder then it turns to the S 70° W direction. The continuation of this zone to the west has not yet been studied. It just forms a typical S-shaped zone, its eastern and western ends are elongated along the main tectonic axis of the later Permian movement, and its middle portion cuts the older tectonic line of Silurian beds at an angle of about 90° as seen in the Hugola area. The middle zone is formed by some large but isolated rock masses chiefly in Chungkengola, Bainola and Chaokungder. These masses are arranged in a direction parallel to the inner zone. The outer zone, or the southern zone, is the zone of Usnahi from which it continues to the southeastern side of Bainola. The isolated rock masses of the middle zone topographically form the Chungkengola and Chaokungder high lands with an elevation of about three hundred meters above the mean level (900 meters above sea level) of this region. The Usnahi, Siaobaliang and Hugola regions are upland regions not higher than one hundred meters above the mean level. These S-shaped ultra-basic zones were probably produced by a huge shearing force which formed a S-shaped weak zone and then intrusives filled in. The ultra-basic rocks and their later accompanied rocks are directly in contact with the Palaeozoic volcano-sedimentary rock complex.

The ultra-basic rocks are generally moderately differentiated and consist of two principal types:

(1) Dunite-harzburgite and buchnerite-peridotite type with latter gabbroic and even more acidic rocks; (2) Dunite-monoclinic pyroxene peridotite-peridotite type with latter gabbroic, dioritic and other acidic intrusives.

Rocks of the first type constitute the inner zone of the eastern region and the Malai-Sum mass, and of the second type constitute the middle zone of the same region. The ultra-basic rocks of the outer zone and other places have not been studied fully. It is the endomorphism and partly exomorphism that the peridotic rocks changed to serpentine rocks, which have since been classified as pure serpentine and bastite serpentine of which the former being the serpentinized dunite, the latter being the altered pyroxene peridotite and peridotite. Where the olivine minerals altered to chrysotilite and antigorite, sometimes cerolite, talc, chlorite etc. and the pyroxene minerals changed to bastite and carbonate minerals. Serpentine rocks of the inner zone contain chiefly minerals as chrysotilite and cerolite, sometimes also antigorite with bastite pseudomorphs after pyroxene, which latter contains very little secondary minerals as magnetite and calcite. Serpentine rocks which constitute the rock masses of middle zone mainly compose of antigorite and secondary anhedral magnetite, sometimes also chrysotilite with bastite richly disseminated with magnetite and calcite, where the fine grains of magnetite fill in the cleavaged spaces of bastite and the bastite sometimes being replaced by calcite. The accessory constituents of the rocks are also different in the different rock types, of which the rocks of first type as seen in the inner zone contain more chromite, sometimes also magnetite, and of the second type as occurring in the middle zone are much richer in titaniferous magnetite, and sometimes also sulfide minerals. By the study of the malformation-crystals of pyroxenes, we find that the pyroxenes of the first type of rocks are mainly enstatite, sometimes with nearly equal amount of undetermined monoclinic pyroxene, of which the former forms the minerals of rocks of the normal dunite-harzbergite-peridotite type, and the latter forms the sub-type of dunite-buchnerite-peridotite..

The main chromite deposits as having been discovered by us are confined to the inner zone of rock type of dunite-harzburgite-peridotite and its subtype of dunite-buchnerite-peridotite. In the area of the middle zone, the rocks of the dunite-monoclinic-pyroxene-peridotite-peridotite type contribute us but very scattered and some smaller pockets of chromite.

Both of the two types of rocks are moderately differentiated and usually without sharp lines between the rocks in contact. But it is evident that the rocks were formed at two stages, the early and the latter stages. In the early stage the former dunite, pyroxene peridotite and peridotite crystallized from the magma which formed a short and incomplete cycle of magmatic segregation; and in the later stage the later dunite, pyroxene peridotite, peridotite gabbro, dioritic and other acidic rocks crystallized from the residual magma and formed a long and complete cycle. By the deformation and brecciation of the older rocks accompanied by the corrosion and stoping of the latter magma, the rocks of the first cycle formed as roof-pendants and xenoliths of the later rocks, of which the xenoliths are in rounded shape of different size and with sharp lines between the rocks of these two stages. Along the weak zones of the deformed rocks are usually occurred as dykes, ring dikes and rock masses. In the middle portion of Chaokungder the older peridotite forms the central core with a rim of later dunite and an outer rim of gabbro. In the proper Hugola area later dunite occurs as dikes. The xenoliths of the eastern Chaokungder are dunite blocks in peridotite, and in the Hugola area harzburgite and peridotite xenoliths in dunite. In the Malai-Sum area almost all the older peridotite blocks are as xenoliths in the later dunite. The longer axes of the different xenoliths range from a few centimeters to one hundred meters long. Xenoliths occurred as angular forms are occasionally found in Malai Sum and other areas, but not so common as the rounded ones. A common fact being observed in all of the areas, except the Chaokungder, that the rocks of the early stage are all in pale yellowish to grayish brown colour as seen near the outcrop and not far from it below. The rounded xenoliths are generally with irregular cracked brown cores and hard greenish crusts which exhibiting perpendicular joints. Both of the early and later rocks were strongly serpentinized by later actions.

Chromite deposits found in the later dunite, as seen in the Hugola area and other places, are usually accompanied with the smaller older xenoliths and the ore bodies sharply contact with their surrounding rocks. Another chromite deposit occurred in the Hugola region is near the metamorphosed andesite which makes the roof of the latter dunite. All of these so far discovered deposits as related to the late magmatic stage are situated on the upper portions of their related rock masses. Chromite deposits as discovered in older dunite are in disseminated forms without any sharp margin to their surrounding rocks.

Later gabbroic, dioritic and granitic rocks are all in a dike form penetrating both the early and later peridotitic rocks. Saussuritized gabbro and altered hornblende gabbro are generally associated with the chromite deposits of the later stage, as well as the chromite ore bodies are controlled by the early structures.

The chromite deposits of Hugola and Hugola-Bainola are as follows:

1. The Hugola chromite deposits.

Hugola is a broad upland with rolling hills and open valley and almost the whole area is covered by Tertiary sediments and recent eolian sands. It occupies in the middle portion of the S-shaped inner zone of the ultra-basic masses. Here the ancient sediments are the metamorphosed andesite, andesite porphyry, basalt and jaspilite with lenticular marble as seen in its south-western portion, and metamorphosed andesitic tuff, rhyolite, jaspilite and tuffaceous sandy beds seen in its north-eastern portion. They constitute the hanging wall of the intrusives and form three blocks of roof-pendents in their later magamatic rocks. All of these old beds strike N 45-60° W and dip to SW at angles of from 50° to 70°. The directions of the longer axes of the roof-pendant blocks are in N 30-35° E and with a same dip as well as the ultra-basic rocks to the south-east at an angle of about 45° to 60°. Newer beds of sandy shales and sandstones with conglomerate of Mesozoic Age lied above the Palaeozoic metamorphosed volcano-sedimentary beds and the intrusives in the eastern, northern, or even western margins of the Hugola area. The prevailing eolian sands make it difficult to fully study the real appearance of the underlying floor rocks. Ultra-basic rocks of both the two stages are discovered in this area. Rocks of the early stage are mostly encountered on the eastern side of the peridotitic mass. They form both as the hanging wall and also as as roof-pendant or xenolith of the rocks of the later stage and constitute a series of rocks of dunite, harzburgite and peridotite, of which dunite occurred near the hanging wall as observed. Rocks of the early stage are all in pale yellowish brown or grayish green, sometimes they consist of pseudo-phynocrysts of bastite of pale green to dark green with fine perfect cleavages. After serpentinization the older rocks are always in reticulated texture, and the unaltered pyroxenes are mostly enstatite sometimes also monoclinic pyroxene of undetermined species. Both of the early and later rocks mainly belong to the dunite-harzburgite-peridotite type, sometimes also the subtype of dunite-buchnerite-peridotite. In the early dunite, chromium minerals may be found as accessory minerals. Rocks of later stage mainly occur along the western portion of Hugola, and they belong to dunite-harxburgite-peridotite type, of which the dunite occurs near the margin of the foot wall and constitute the main bulk of the later rocks. They are all in pale green to dark green colour with slightly banded and amorphous textures. The chromite deposits in this area are closely related the later rocks, especially the dunite. Other intrusives, such as saussurized gabbro and altered hornblende-gabbro, even the comparatively rare occurring allivalite and feldspar-peridotite are nearly all in forms of dikes along the directions of N 30-35° E, same as the main tectonic lines of the peridotitic rocks. Of which saussuritized gabbro is more common than others. Almost all of these dikes possess the same dips of from 40° to 60°

to south-east. They intruded in both the early and later magmatic rock masses as described above. Granite porphyry occurs as a dike in the southern portion of this area.

Chromite deposits first discovered in this area are in the southern portion of the ore deposit of irregular lenticular shapes arranged in a nearly south to north direction, the middle portion more or less of lenticular masses in a direction of N 32° E, and the north portion of irregular pockets. These three portions constitute a zone of N 32° E in direction, just same as the main tectonic direction of this area.

The southern ore occurs in dunite to harzburgite rock complex, the direct ore bearing rock is dunite which is situated between two blocks of roof pendant of the old metamorphosed volcanic rocks. The chromite irregular lenticular masses are more near to the eastern one of the two blocks, which makes the hanging wall of the ultra-basic intrusives. At the contact between dunite and chromite there is a brecciated and chloritized zone. The contact lines between dunite and ores are sharp. Dikes of gabbro which has been saussuritized, cut this chloritic clay zone and divide the chromite lenticular bodies into two separate parts and partly in contact with the lenses. From this zone westeraid dunite gradually changes to harzburgite and is cut by gabbroic dikes. The chromite lenticular masses, arrange in two rows in a same direction of about N 15° E with dips to south-east at angles of 40° to 50°, which is same as the old hanging wall. The ores are granular in texture with very little chrysotilite and chlorite filled the spaces between the granules. Secondary carbonates and siliceous materials occur in cracks and joints of the ores. The ore bodies have been brecciated by the later movements with marked striations on the polished surface, but the displacement of faulted blocks is rather small that it may be sometimes neglected in consideration.

The northern ore is one of more irregular shaped pockets with a dip angle of about 60° and with strike of about N 32° E. This ore is embodied by the early peridotite but it is closely related to the underlying later dunite. The ore is massive with higher tenor.

The middle ore is found between the southern and northern ores. It consists of numerous irregular lenticular bodies which are nearly all arranged in a direction of from N 30° E to N 35° E. some in N 10° W. The ore bodies are all of disseminated forms. They are sharply in contact with each other and with the surrounding rocks of chloritic clay materials of altered dunite with including rounded bodies of early harzburgite and peridotite ellipsoids. Saussuritized gabbro forms the foot wall of the ore bearing zone. Both of this zone and of the saussuritized gabbro dip to south-east at angles from 45° to 60°, and both of them have been cut by a series of cross faults with horizontal displacements of from ten to several tens meters.

These chromite deposits are closely related to the later dunite and controlled by early structural lines and disturbed by later movements. The ores are all rich in alumina.

2. The Hugola-Bainola chromite deposits.

This area contains the north-eastern part of Hugola and the western part of Bainola. These two parts are separated by an open valley of the intermittant Baingol River which connects the Bain-Nor basin and Dabusu-Nor basin. These two parts are occupied by a same mass of ultra-basic intrusive of which the middle part is covered by alluvial deposits. Almost the whole area has been covered by the Cenozoic beds especially the recent eolian sands. The few outcrops are found on the tops of the rolling hills and on the steeper slopes of the Baingol valley. The altituds of this area is similar to the main portion of Hugola. The older beds, or the Palaeozoic beds, strike N 60° W with dips of the southwestern portion being from 50° to 70° angles to the southwest, and of the north-eastern portion to north-east of angles from 45° to 60°. The beds are composed of metamorphosed andesite, andesitic tuffaceous sandstones and rhyolite. The axial portion of the anticline is the ultra-basic rock mass. The basins along the marginal portion of this area are formed by the Mesozoic sandstones and shaly beds with basal conglomerate of low dip angle. Tertiary clay and sandy beds usually may occur just under the eolian deposits.

The ultra-basic rocks belong to the dunite-harzburgite-peridotite type of both early and later stages. The early rocks are mainly dunite and occurred on south-western part of the Hugola portion of this area. The later stage rocks are well differentiated to dunite, harzburgite, peridotite. Late saussurite gabbro, diorite, sometimes eclogite, allivalite and feldspar peridotite always occurred as dikes in directions of N 15° W and N 60° W.

The chromite deposits in this area are both discovered in the Bainola portion and in the Hugola portion. Chromite ores discovered in the Bainola region are lenticular ore bodies of late magmatic stage which occurred in dunite with a zone of clay materials of serpentine, chlorite and talc. Ores of the Hugola portion are in disseminated form in the early brownish dunite. These disseminated ores are rich in iron.

The ultra-basic rocks and chromite deposits of the Silinkolomon area as described above can .he summarized as follows:

(1) The ultra-basic rocks of the Silinkolomon area are distributed in a part of an arched anticlinorium of late Palaeozoic geosyncline which probably startmg from Mongolian Altai, passing through Ulantzabumen to Silinkolomon, and then to theeastern Inner Mongolia. The arrangement of the rock bodies of this area is in a direction NEF-SWW.

(2) The ultra-basic rocks are as intrusives in the strongly deformed metamorphosed volcano-sedimentary beds of from Silurian to Permo-Carboniferous Age.

(3) The crystallization of the ultra-basic rocks are defined as two different stages but originated from the same magma. The early rocks are dunite, pyroxene-peridotite and peridotite forming a short cycle, and the later rocks are dunite, pyroxene-peridotite, peridotite, gabbro, diorite, and more acidic rocks which rendered a complete cycle.

(4) Rocks in the eastern area are clearly shown as three zones of which the inner zone is S-shaped, the middle zone is formed by isolated masses of rocks, and an outer zone has not yet been fully studied.

(5) The rocks are moderately differentiated and classified as two types: the dunite-harzburigite and buchnerite-peridotite type with late allivalite, gabbros diolite, and even more acidic rocks; and the dunite-monoclinic-pyroxene-peridotite-peridotite type with latter gabbro, diorite and more acidic rocks. Rocks of the former type formed the inner zone and of the second type formed the middle zone.

(6) Chromite deposits are closely related to the dunite-harzburgite-peridotite type of rocks of the later stage, and mostly discovered in the Hugola and Hugola-Bainola region.

(7) Chromite deposits in forms of massive and disseminated irregular lenticular masses and pockets are chiefly found in dunite or in the complex zone of dunite and peridotite. They are mostly occurred in upper portions of the later rocks and controlled by former structures with clay zones, and sometimes disturbed by latter structures.

(8) Chromite deposits of early magmatic stage being in disseminated form of poor tenor.