ALKALINE INTRUSIVES OF LUTINGSHAN AND CH’IAO SHAN IN S. SHANSI

By E. T. Nyström & S. T. Tsoo

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INTRODUCTION

In recent years several localities of highly alkaline rocks have been discovered in Shansi by the National Geological Survey of China and the Sino-Swedish Research Institute. The results of investigation in this line up to 1927 are embodied in the paper: "Some Alkaline Rocks of Shansi Province, N.

* Received for publication in November, 1932.
It is pointed out in this paper (p. 153) that in other parts of the great country of China the known localities of alkaline rocks are exceedingly scarce, a fact which may not be explained solely through lack of detailed investigation, but may also be due to the exceptional tectonic structure of Shansi.

The main tectonic features of Shansi have been elucidated by B. Willis, E. Nyström, C. C. Wang and others. See map, fig. 1 reproduced from above-mentioned report by Nyström. The province may be divided in three parts:

1) The strongly folded-Mongolian border-land to the north
2) The central part: A plateau, here and there folded and faulted.
3) The southern part, where the Tsingling range begins to exert its influence.

The tectonics within each of these three zones are governed by characteristic trendlines: in the north proceeding parallel with the folds from NE to SW, in the central area represented by great faults (but also folds) running NNE-SSW and in the south mainly having an E-W direction. But the NE-SW trendlines so strongly developed in the north make also an appearance here and there both in central and south Shansi.

The known areas of Shansi alkaline rocks are all situated near or within regions where different systems of trendlines meet, that is to say where the crust has been in a manner prepared for their intrusion.

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Three areas of alkaline rocks are at present known in Shanxi:

1) The central Chiao-ch’eng (Huyehshan) intrusives about 65 km W of
the capital Taiyuan.

Fig. 1. Trendlines in Shanxi, mostly according to Siesm.
2) The intrusives 20 to 60 km. ESE, SE and SSE of Linfushan (Pingyang) in S. Shansi. The localities described in the present paper belong to these.

3) Tsuchinshan, about 160 km. WNW of Taiyuan.

The intrusives dealt with in this paper were discovered independently by G. B. Barbour and E. T. Nyström in 1930 and the survey was done by E. T. Nyström and S. L. Tsao in 1931.

The authors of this report are greatly indebted to Professor P. Quezel of Stockholm University for good advice liberaly tendered.

In all the three localities enumerated above it is possible to trace the evolution back to a parental magma of dioritic composition. The differentiation has followed three different directions: In Chiosch'eng a granite and syenitic evolution, resulting ultimately in norite and anorthosite-syenite (hornblende-bearing). In Linfushan district a granite, syenite and dioritic series leading up to quartz-porphry, anorthosite-syenite (albitized) and harnatic respectively. In Tsuchinshan only a syenitic evolution resulting ultimately in leucite and nepheline tinguite. See diagram Fig. 2 (reproduced from Nyström: op. cit. p. 139.)

Fig. 2. Differentiation along the granitic (Gc), syenitic (Sy.) and dioritic (Dl.) series in Chiosch'eng, Pingyang and Tsuchinshan.
The intrusives described in the present paper are not far distant (10-12 km) from the main occurrence—Lungwanga—is in the Linfen area and exhibit, through consanguinity and similar differentiation, a strong relationship with the parent magma, of which they may be called distant satellites. Cfr. op. cit. p. 100-127.

LOCATION AND TOPOGRAPHY

Looking eastwards from station Mengch’eng (蒙城) on the main southern motor road in Shansi (that is to say just NE of the abrupt bend in the river Fenho (汾河) it is possible on clear days to see the curious jagged rim of the Lutingshan (棟山) intrusive (Pl. I, Fig. 1) and also farther east a strange cross-shaped mountain which is obviously of different composition to the country-rock. The latter is the Ch’iaoshan (橋山). The river Fenho itself, through its very abrupt change of direction from NNE-SSW to almost E-W seems to indicate, that different trend-lines meet here, and that consequently (see above) there may be a possibility of finding alkaline intrusives here.

Lutingshan represents the highest eminence of a promontory plateau lying between the Fenho valley and the Yich’eng (翼城) plain and the very tip of the plateau jutting out towards SW has been reinforced by the intrusive contained in the S slope of Lutingshan. Ch’iaoshan is also what we may call a "shoulder" intrusive. It is situated 3 km. ENE of Lutingshan and 11 km. SW of T’asim (塔似) the prominent western eminence of the Lungwanga intrusive (see above).

The wedge-shaped plateau in question presents little of topographical interest. It is fringed at the base by loess and eroded in rather narrow canyon-like valleys above. But the Lutingshan intrusive, as will be described below, is certainly a topospheric phenomenon of rank. Ch’iaoshan, on account of variety of rocks and different resistance to erosion, appears as a collection of steep cone-like projections.

North and northeast of Ch’iaoshan there is a row of separate rounded hills arranged very regularly along a nicely curved line. Each of these hills harbours an intrusive and the significance of the curved line will be dealt with later.
Standing on the top of Lutingshan (1132 m. above sea-level) one can see the Fenbo valley towards the west, but the river there is invisible on account of the masses of loess. Towards SW however it appears as a silvery streak meandering away in the distance. From Ch’iaoshan (1162 m.) a comprehensive view over the Yich’eng plain is obtained with the low Mt.shan in the centre which also harbours an intrusive (Nyström: op. cit. p. 115). Pl. 1, fig. 2 shows a view from the northermost and highest peak of Ch’iaoshan across the SE part of the intrusive and the neighbouring part of the Yich’eng plain.

STRATIGRAPHICAL FEATURES OF ENVIRONMENT

The wedge-shaped plateau, on the fringe of which the intrusives are situated, is mainly built up of Ordovician limestone with gentle dips of 12°-15° towards NW. The highest part of Lutingshan, as well as a larger area towards NE, consists of Carboniferous shales and sandstones, which in their basal parts contain nodular iron-ore. A few hundred m. east of village Changchuiwan a number of these nodules of a size up to 0.5 cub. m. are weathered out, lying scattered on the ground. In the northeastern Carboniferous field some coal-mining is carried on especially near village Shapat’o (= 岗坡).

TECTONICS OF ENVIRONMENT

A glance at the map, pl. IV, will show not only the fault regular and gentle dip of the country-rock, but also the fact that the plateau-like structure is broken by fault-lines north of Lutingshan and NE of Ch’iaoshan and it appears that the latter intrusive is bordered towards SE by a similar break in structure. The direction of these faults is highly significant. As indicated above we have here a dual influence of the Foshan ridge lines running E-W parallel to the lower course of the Fenbo and in direct line with the mountain-range following the Fenbo river on its northern side, (which range is the upthrow of a fault) and the SW-NE trend lines which as mentioned before make their appearance in all the tectonic zones of Shaanxi. C. C. Wang (op. cit. p. 74) says: "From the general direction, it seems probable that the Hoohan fault is more or less continuous with the Fenghuangshan fault though the fault west of the Foshan ridge and across the Yich’eng plain." It should be explained that the Fenghuangshan fault, running more or less SW-NE, is one of the major features of the SW corner of Shaanxi. See map, fig. 1.
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This is an undeniable confirmation of the fact that alkaline rocks in Shanzi are often to be found where two systems of trendlines meet. Indeed, judging from the numerous satellites of Ch‘iaoshan, it is just here where the weakening of the crust has taken place.

As for the Lutingshan intrusive there are no satellites found so far. The magma has forced its way upwards in an explosive manner and has crumbled up the limestone strata on its western side in the action of forcing its way through the sediments. It has not been such an easy work as at Ch‘iaoshan.

THE ALKALINE INTRUSIVES

As already mentioned above, there are two main intrusives in this region separated by a distance of about 3 km. One is situated on the southern slope of Lutingshan and the other is Chiaoshan which is an independent unit on the S fringe of the plateau.

I. THE ALKALINE INTRUSIVE IN LUTINGSHAN

Mode of Occurrence

This is a volcanic neck almost circular in section with a max. diameter of 1.9 km. The most striking feature is its topography. Through the central rock having been profoundly altered and rendered soft and perishable and thus become an easy prey to erosion, while the rim has remained fresh and hard and unattacked except for two valleys where the water has made its way from the interior of the neck, the result is the formation of a grand amphitheatre or "pseudo-crater" of about 1500 m. diameter and something like 200 m. in depth. Pl. II, Fig. 1 gives a view from the interior of the intrusive showing the soft, rounded rocks in the foreground and the hard, jagged rim towering above. These topographic features are absolutely without parallel amongst the other intrusives in Shanzi. The rim especially towards NW is developed in characteristic "shark's teeth" (see Pl. III, fig. 1), but the southern rim shows more normal erosion. The reason why the water has opened up a wide valley here is because of the existence of easily attacked limestone "inlets", the other exit—towards SW—is narrower and canyon-like. There are no inlets here.

Cleavage

Cleavage is more developed in the Lutingshan intrusive (and even more so in Ch‘iaoshan) than in any other area of alkaline rocks in Shanzi. It is best
studied by entering the SW canyon and proceeding to the stone-quarry inside the rim. It is noticed that there are two systems of cleavage fissures, viz. one less pronounced running almost N-S with vertical dip and another very strongly developed running ESE-WNW also almost vertical. On the photograph, Pl. II, Fig. 3, the latter cleavage is very clearly visible and it continues also through the rim. It is significant that this cleavage direction is parallel with the main fault just N of Lutingshan.

**Contact Action and Inliers**

Contact action is very marked in the Ordovician limestone surrounding the volcanic neck but it does not extend very far. The contact features are rather constant all round the intrusive, thus:

1) at 100 m. distance from the igneous rock: Small veins of iron-ore or pyrite. Sediments often tilted.

2) at 50-100 m. distance the limestone is white and powdery.

3) at 0-50 m. distance the limestone is changed to a peculiar fine-grained, almost dense bright grey crystalline rock. This being easily eroded often shows a depression in topography.

Contact action is less pronounced here than at Ch'ingshun, indicating a sudden and violent break-through and comparatively speedy termination of igneous activity.

In the SE part of the Lutingshan intrusive there are two "inliers" of limestone. Such inliers are very frequent in the Shansi intrusives (cfr. Nyström: op. cit. p. 85). At the NE rim of the northern inlier in Lutingshan contact action and the presence of mineral solutions have resulted in the formation of a mass of iron-ore about 20-40 m. outcropping. The ore is rather pure magnetite and is associated with celestite, garnet and other contact minerals (See Pl. II, fig. 2). The limestone of the inliers is highly metamorphosed and is partly converted to white marble. It is being utilized for making quicklime in some mines nearby.
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**Rim and Centre. Petrographic difference**

The remarkable topographic features of the Lulingshan intrusive make it necessary to assume the existence of petrographic differences in composition. This is proved by microscopic examination, but it will be seen that such difference is caused rather through alteration and decomposition (almost prepyritisation) perhaps through hydrothermal agency having attacked the centre, than through any fundamental and original difference in magma composition. The transition between the central and the rim rock is always gradual.

The rim is rather uniform in composition though here and there the felsic constituents may show some increase. A specimen taken from the SW part of the rim, 700 m. ENE of village Shih-anhe (石猴子) shows the following macroscopic characteristics:

The Lulingshan rim-rock shows great similarity to the émerite of Tung-t'ainshan (op. cit. p. 118). It is a fresh, light greyish pink medium-grained rock, sparsely sprinkled with black biotite at needle-shaped crystals or in larger patches. At closer scrutiny the feldspar appears as minute, glinting, lath-shaped prisms. Weathering is light brown and not strong.

Under the microscope the rock is seen to be a hypidiomorphic fabric of crystals of very different size, the largest and most frequent crystals being a plagioclase of the composition of andesine (An—35-45%) twinned according to the albite and periclase laws and often zonary. Orthoclase, strongly perthite, exists but is less than half in quantity compared with plagioclase. Amongst the more important constituents we have also green hornblende and light green augite.

Also a fair amount of quartz as filling and accessory sphene, biotite, magnetite, apatite, zirconite and secondary calcite.

The plagioclase crystals are as a rule short, lath-shaped, interlocking with jagged edges, they contain much included substance but the rims are fairly unaltered.

The perthitic nature of the orthoclase suggests tenure of sodium.
Very characteristic for this rock is frequent micropegmatitic graphic fabric of intergrowth of quartz and orthoclase.

Of the biotites (which in some samples assume a rather important role) the hornblende has strong pleochroism between dark green (parallel to b) and light greyish green. The augite is faintly green and has extinction angle up to 45°. The biotite which is very subordinate has pleochroism between tobacco-brown and almost colourless.

The quartz which is present to an amount of about 1% only shows somewhat undulous extinction.

This rock is undoubtedly of more dioritic composition than the Tungt'ai-shan biotite and may be classified as a basaltic near to biotite. In the main intrusive area of the neighbourhood (the Lungtsuangmao region, cfr. op. cit. p. 112) the westernmost part is also of basaltic composition.

The rim is about 200 m. wide and proceeding towards the centre of the neck we arrive after a gradual transition to the central rock which has a very different outward appearance.

A sample was taken at the quarries above-mentioned and shows a bright reddish pink rock with indistinct, rather regularly scattered patches of altered, greyish green biotites.

Under the microscope the rock is seen to be very strongly affected by some alteration process which may be propylitisation rather than weathering. The main constituents have obviously been as in the rim-rock plagioclase and orthoclase with the former very much preponderant. The alteration has been so intense that it seems that the feldspar has been replaced almost without trace by calcite which indeed occurs in large patches with uniform extinction. The rock effervesces with acid.

The biotites have been almost completely altered to chlorite. A little biotite remains. As accessories we find magnetite, apatite, zirconite, fan-shaped chlorite and mica. Interstitial quartz is present.

The central rock is probably fundamentally the same as the rim but has been powerfully altered by some agency stronger than ordinary weathering.
may have been some hydrothermal agent which has caused this at or shortly after the intrusion. In the Banat intrusives there are similar features to be observed.

In this connection it is also of interest that another of the Lüftel (Pingyang) intrusives, viz., Liangshih-p'0 (cfr. Nyström: op. cit. p. 126) has suffered hydrothermal or pneumatolytic influences which in this case has resulted in analcimisation.

In the NW part of the rim and also in the SW canyon it is possible to find veins in the rim which however are very scarce and do not penetrate outside the rim. They are up to 7 cm. in width of very light pinkish colour, very dense aplite texture with a few phenocrysts here and there. Uniform composition in centre and borders. No contact action either in vein or in side-stone. Very firmly united with the latter. Under the microscope a porphyric texture is apparent. The groundmass is very fine and even grained consisting of quartz and orthoclase and the few phenocrysts consist of orthoclase with highly corroded edges and plagioclase, the former predominant. The accessories are very few and consist of biotite (pleochroism dark brown to almost colourless), light-coloured mica and magnetite. This is an aplite of granite composition. There is a similar differentiation-product in the Lungwangnian intrusive, viz., an alkali-granite of apparently identical composition and outward appearance (cfr. Nyström: op. cit. pp. 112 & 113).

The existence of these veins help to throw some light upon the hypothetical process of intrusion which may perhaps have shown the following stages:

The neck has been formed through a quick, almost explosive penetration of the sediments which have been badly crumbled up in the process. A "chilled margin" (the rim) has first been formed while the interior continued some time in a liquid state and sent out veins which penetrated cracks in the rim. By pressure being relieved above, water vapours have been allowed to percolate through the pressure in its last stages of liquefaction and thus the strong hydrothermal action upon the central rock may at least partly be explained. Ordinary weathering is certainly not sufficient to explain the highly calcified nature of the central rock. It is not common to find a volcanic rock so full of carbonate as to effervesce with acid.
II. THE CH’AO SHAN INTRUSIVE

Mode of Occurrence

From 3 to 4 km. ENE of Lutingshan a group of intrusives may be found the largest of which is Ch’ao Shan, the northern peak of which, very steep and crowned with an old temple, is a very conspicuous feature in the landscape (Pl. III, fig. 2).

Thanks to a contact-metamorphosed fringe of easily eroded crystalline limestone the northern part of Ch’ao Shan is very completely sculptured out and standing on the northern plateau one can see the deep depression just north of the peak and the two semicircular riverbeds which embrace the intrusive (See map, pl. IV). Towards the south the intrusive widens out along what is apparently a faultline running SW-NE.

Coming from Lutingshan after an easy walk across the level plateau one has to descend to the contact zone and then follows a most arduous climb zigzagging up the steep northern slope which is about 80 m. high. Or the peak may be climbed from the south and this is the regular path to the temple which is built on the highest peak of the mountain (See Pl. III, fig. 2). There is a stone staircase about 110 m. high on this side. The rest of the mountain consists of lower peaks, some craggly others more smooth (See Pl. III, fig. 3).

Satellites

In contrast to Lutingshan Ch’ao Shan is endowed with a great number of satellite intrusives only a few of which are shown on the map. Up on the plateau to the north there is quite a chain of them visible as high rounded hills placed in a nice curve running first ENE and then NE as a result of the dual influence of the two systems of trend-lines (see above). Towards NE the direction of this chain points right towards the centre of the Lungwagami So intrusive. The satellites consist of a strongly weathered rock which apparently is an akriti porphyry. They vary in size between a few m. and several hundred m. and occur both as stocks, dikes and sills.

Cleavage

Nowhere else in the Shanxi alkaline areas is there such a strong cleavage exhibited as in Ch’ao Shan especially the northern part of this mountain. Pl. II,
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Fig. 3 gives a good idea of the extreme fissuring of the local coarse porphyry here. As in Lutingshan the cleavage follows one of the important trendlines viz. the ENE-WSW fault direction and its dip varies from 45° to 75° mostly approaching the larger figure. According to Cloos cleavage reflects the movements during the course of intrusion and it seems likely that the fault-action in question has been in operation during the intrusion of the magma.

The strong cleavage above mentioned does not seem to extend very much south of the northern peak. But viewing Ch’iao-shan from a distance it is possible to notice also a distinct cleavage dipping 5° to south which runs through the mountain in fissures separated 10 m. or more and thus produces a banking effect.

Contact Action

This is stronger than at the Lutingshan intrusive and it is possible that the rock has been the channel of a superimposed volcano and that the magma has therefore been able to exert stronger effect on its surroundings. The metamorphosis of the country-rock (Ordovician limestone) begins about 200 m. from the intrusive and shows itself through the appearance of white powdery marble with frequent small dikes of volcanic rock. Between 50 and 25 m. from the border line the limestone is grey soft and crystalline then 20 m. or so of hard grey almost dense crystalline limestone, then a narrow strip of white marble and then the contact which is marked by a natural trench ½ m. wide. The metamorphosis is best studied in the depression just north of the main peak of Ch’iao-shan.

 Petrographic Description

In Ch’iao-shan there is a greater variety of rocks than in Lutingshan and the rapid changes are typical of a true alkaline intrusive.

The high northern peak consists of an extremely weathered, fissured and crumbling pink porphyry of coarse texture with closely packed white oblong felspar crystals mostly 2 x 4 mm. in size, loosely cemented together. The rock is so friable that no slide could be made.
In the valley south of the peak the rock becomes more firm but is here strongly microlithic with cavities up to $6 \times 10$ mm. partly filled with rusty material. It is a light pinkish rock with felspars in glistening laths up to $2 \times 4$ mm., mostly even-grained but here and there one can see phenocrysts of felspar up to $10 \times 12$ mm. in size. Dark biotites are irregularly scattered throughout, mostly in minute crystals. Weathers greyish brown. Since this rock represents a fairly large average of the intrusive a chemical analysis was made and this is seen below.

Under the microscope this rock shows a very large preponderance of extremely porphyric alkali felspar with only a few large plagioclase crystals and interstitial quartz about 2%. The rock seems fairly fresh.

The albite spindles in the perthite are arranged along crystallographic planes resulting often in a zonary appearance.

Accessories are present in very small amount. They are biotite, green hornblende, sphene and magnetite.

This is obviously a highly alkaline rock and this is confirmed by the analysis.

The SE peak visible on Pl. 1, fig. 2 contains a dyke of almost snow-white rock with scattered rusty patches and microlithic cavities partly filled with brown ferruginous substance.

Under the microscope the rock is seen to be a porphyry with closely packed (periclasic texture) idiomorphic felspar crystals mostly $1\frac{1}{2} + 2\frac{1}{2}$ mm. in size. The great majority of these phenocrysts are a twinned plagioclase (andesine) but there are also a few porphyric orthoclase crystals. They have all highly corroded edges and with their rectangular shape and jagged edges we may use a crude metaphor and say that they are like postage stamps. The groundmass consists largely of fine-grained quartz with alkali felspar and very little plagioclase.

The large felspars are abundantly speckled with sericite. The very scarce accessories are: magnetite, leucoxene, apatite and colourless mica. Biotites are absent.
This dyke rock is a basaltic porphyry and shows the local tendency of the differentiation towards quartz-diorite magma.

In the same neighbourhood there is a small outcrop of a highly altered rock similar to the central part of Lutingshan intrusive. It has the same red to pink colour and contains altered biotites in green patches. Under the microscope the rock is seen to contain felspar much altered to sericite and calcite and there are large individuals of the latter mineral. Quartz is present as well as hornblende altered to biotite and chlorite. Accessory such as zirconite, apatite and magnetite have resisted the decomposition. The presence of this rock shows that also the Ch’iaoohan intrusive has been subject to hydrothermal action during the late stages of solidification, though the extent of such action is comparatively small.

To emphasize still more the similarity of differentiation in the two intrusive apolitic veins of granitic composition are also to be found in Ch’iaoohan. A sample from the valley south of the northern peak has the following characteristics.

It is a dense, apolitic rock of pink colour, the width of the vein being 9 mm. Under the microscope it is seen to be of inequigranular texture with groundmass of quartz and alkali felspar and phenocrysts of plagioclase and perthite, especially the former being influenced by the groundmass so as to produce brown reaction rims, though the edges are rather smooth. The vein seems to have a “chilled margin” of exceedingly fine grain, almost microschistic. Accessories are epidote, sphenite and magnetite.

In the SW part of the intrusive a sample was taken 500 m. W. of the village Yang=out (羊頭村). The rock here is of pinkish grey colour and porphyritic texture and shows large green-patchy patches. Under the microscope it is seen to be a porphyry in which the large phenocrysts are rather scarce and seem mostly to be andesine. They contain much epidote which also occurs in large individual patches and accounts for the above-mentioned green-patchy areas. The groundmass is dominantly and contains alkali felspar and a little plagioclase and quartz. This rock may be called an epidote-bearing olivine. Diopside and hornblende are also present.
To summarize the character of Ch‘ioshian intrusive it may be said that the rocks are all derived from a parent magma of felsic composition and that the chief differentiate is a quartz-syenitic (nordmarkite) rock of decided alkaline nature. The composition of the stock varies a great deal and differentiation has proceeded in a dioritic direction (banasite perpyhyry) as well as along a granitic stem (granite aplite). As in the Lungwangniao region the amphibole and pyroxene are all of ordinary (not alkaline) type.

The chemical character of the chief differentiate (the nordmarkite) is shown by the following analysis:

**Table 1. Analysis of nordmarkite from Ch‘ioshian, S. Shensi by N. Sahibom**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Mol. Prop.</th>
<th>Norm</th>
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<tr>
<td>SiO₂</td>
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<tr>
<td>Al₂O₃</td>
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<tr>
<td>Fe₂O₃</td>
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<td>FeO</td>
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<td>MgO</td>
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<td>CaO</td>
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<tr>
<td>Na₂O</td>
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<tr>
<td>K₂O</td>
<td>5.82</td>
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</tr>
<tr>
<td>H₂O (295°)</td>
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<tr>
<td>TiO₂</td>
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<td>P₂O₅</td>
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<td>MnO</td>
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<td>100.42</td>
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</tr>
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</table>

Quantitative System: 1 : 5 : 2 : 3 Pulaskite

This rock is of decidedly alkaline nature and in confirmation of the statement (cfr. Nystöm: op. cit., pp. 137 & 138) that Shensi alkaline rocks although separated by considerable distances exhibit, with regard to certain funda-
Differntiation and evolution of the local alkaline rocks

If it is true that a distinct relationship or cogenetivity exists between all the Shansi alkaline rocks however distant from each other, this resemblance should be still more pronounced between the main intrusive in the Pingyuan (Linfen) area viz. Lungwaungnao and the rocks which form the subject of this paper. Lutingshan and Ch’ingch’eng stacks are no doubt to be considered as satellites (albeit somewhat distant ones) from the parent intrusive Lungwaungnao. The differentiation is also similar.

It may therefore be of interest in this connection to summarize a few important features of the main intrusive. Lungwaungnao is not a stock but a laccolithic body intruded at some distance below the surface of the Ordovician limestone. The parent magma here as elsewhere in the alkaline areas is an akerite, containing chiefly alkali feldspar and plagioclase (oligoclase-andesine) with a little quartz, clinoenstatite, common hornblende and accessories. The differentiation has proceeded along three different stems, viz. a granitic, syenitic and dioritic direction. The first stem shows: akerite—nordmarkite—alk. granite—plitite—quartz porphyry. The second: akerite—aujarite—aujarite syenite (in a satellite only). The third: akerite—bananite porphyry. This three-fold differentiation occurs only in the Lungwaungnao area. A comparative diagram is reproduced on page 266 from Nyström; op. cit. y. 139.

The similarity of differentiation in Lutingshan and Ch’ingch’eng is obvious; but owing to the mode of intrusion, the changes are more quick and localized. Moreover, the stems here as far as we know include only the granitic and dioritic kind. We have here the first three members of granitic differentiation viz.
Akerite—nordeite—granite aplite, but quartz porphyry has not so far been discovered. The aplite represents as stated in a preceding chapter the residual part of the magma which has been injected in narrow veins in already solidified rock, just as Penta Eksela says in discussing larger problems: "Granitic magma might be, to use a metaphor that may sound somewhat vulgar, characterized as the sweat that oozes out from the body of mother earth during the convulsions of orogeny."

The banaitite represents the basic pole of the differentiation and occupies, as in Lungwangnum, mainly the western region whereas nordeite is in both localities is found in the east. The banaitite (cf. Nyström, op. cit. p. 145) constitutes a connecting link between the true alkali-syenitic rocks of central Shanxi and the more dioritic intrusives of central China which are noted for their iron-ore bearing qualities. Coinciding with this we have also in the Lutingshan intrusive along the contact with a limestone infer a fairly considerable mass of iron ore (see Pl. II, Fig. 2) together with garnet and other contact minerals and in the SW part of Ch'ihsian much epidote. Iron ore is not common in the central Shanxi intrusives.

PROBABLE AGE OF THE INTRUSIVES

Although we have here no younger intruded sediments than Carboniferous and thus the upper time limit of intrusion is impossible to define on purely stratigraphical grounds, yet the evident connection of magmatic action with fairly recent diastrophism cannot be denied, thus reducing the problem to the question when the local faultlines were formed.

Considering the intrusives under discussion as satellites of Lungwangnum we may assume a tolerably contemporaneous age and since Eocene strata (cf. Nyström, op. cit. p. 150) in the neighbourhood have been faulted and conglomerates along the faultscars of the Weiho-Fenho grabens are interbedded with Pliocene beds, it is possible that the intrusives date from the closing stages of maximum diastrophism during Oligocene of mid-Tertiary. They cannot be of excessively recent origin since it has taken long time to remove the cover and

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expose hypabyssal rocks. Moreover, this removal must have taken place in pre-Pliocene time since “Hipparion” red clays have been found in Lungwandninao on the igneous exposures. Consequently, in a tentative way, we are inclined to put down their age to Middle Tertiary, though the absence of stratigraphic evidence makes the assumption a purely preliminary and hypothetical one.

SUMMARY

The known areas of alkaline rocks in Shansi are all situated in or near regions where different systems of trendlines meet. As indicated on any map of Shansi by the sudden diversion of the Fenho river towards W we should find near the bend a crossing of trendlines and it is here that the Linfen (P‘ingyang) intrusives are situated. The newly discovered intrusives, which are described in this paper, are Lutingshan and Ch’ioeshan and they may be considered distant satellites of the main intrusive body Lungwandninao (cfr. Nyelton: Some alkaline rocks of Shansi province). They are both typical “shoulder” intrusives, reinforcing the edge of a limestone plateau.

Lutingshan of which the highest eminence consists of Carboniferous sandstone, harbours in its S slope an almost circular stock of about 4000 m. diameter, the most striking feature of which is its topography. The rock composing this igneous body is obviously of two different kinds: the rim showing a jagged “shark’s teeth” contour has offered stronger resistance to erosion, whereas the centre is deeply excavated, the whole resulting in what one may call a “pseudo-crater”, about 200 m. deep. The rim rock is light grey basaltite, inclining to felsite, and the centre a red, easily weathered alteration-product of basaltitic origin, the alteration probably being of hydrothermal nature and having taken place during the latter stages of solidification. There are veins of pink granite-like composition in the rim. There are highly metamorphosed inliers of limestone in the southern part of the intrusive and here a valley provides an outlet from the “crater”. There is also a narrow canyon providing exit towards SW. These topographical features are without parallel in the other alkaline areas in Shansi.

The other intrusive Ch’ioeshan may be seen from Lutingshan at a distance of a few km. towards E. It looks like a dark, cone-like eminence, rising
above the rather undisturbed layers of Ordovician limestone. At closer inspection it is seen that this case represents the northern semicircular part of a boat-like intrusive which spreads along a fault line running NE-SW. It is sculptured in numerous peaks, of which the northern eminence, mentioned above, is the highest. The topography suggests a variety of rocks of different hardness. Ch’iaoshan no doubt marks the spot where, through intersection of trend lines, the crust has been particularly weakened. This is also made probable by the numerous satellites which—in contrast to Lutingshan—are very prevalent round Ch’iaoshan.

The high northern peak consists of a coarse crumbling pink porphyry extremely affected by cleavage. Towards the centre of the intrusive the rock becomes more dense and firm but there are numerous mafic-hyalic cavities. It is of light pink colour and has biaxialate crystals scattered throughout. Since this seems to be fairly representative of a large mass of the intrusive, a chemical analysis was made and the composition is strongly alkaline, but with quartz, in fact a nesomarikite and very similar to certain alkaline rocks of W. Shan. There are dykes, of a snow-white quartzite and veins of granite-aplite, showing thus rapid differentiation both in a dioritic and in a granite direction. The satellites are of basaltic character. Here and there grass-green patches of epidote are seen in the outlying parts of the intrusive. No inliers of limestone have been seen.

Concerning the association of rocks in these two intrusives, they show undoubted consanguinity both with each other and with the parent intrusive Lungwangmiao. From a hypothetical parent rock of dioritic composition there has been differentiation both in a granite (aplite) and in a dioritic (basaltic) direction. The syenitic differentiation (resulting ultimately in nepheline and noscan-bearing rocks) so characteristic for the alkaline areas in W. Shan, is conspicuous by its absence and there are no alkaline pyroxenes (neosine or augite) to be seen. The nesomarikite in Ch’iaoshan is an intermediary member in the granite differentiation process.

Regarding the age of the intrusions it is not possible to arrive at any definite conclusion because of the absence of sediments, contemporaneous, or younger than the igneous action. But since the intrusions are so obviously connected with the Fenho-Weico graben diastrophism, which produced fault-
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scars, along which Pliocene beds are interbedded with conglomerates from the scarps and since, on exposed surfaces of the parent (Lungwangming) intrusive, Hipparion-beds can be found covering outcrops of igneous rocks, it seems that until further information is forthcoming, we may in a preliminary and tentative way establish the time of intrusion to be during the closing stages of maximum disruption of mid-Tertiary time.
Explanation of
Plate I.
PLATE I.

1. Southwestern rim of Luttingshan intrusive from the outside.
2. View from north peak of Ch'iaochan towards southeast across neck and the Yich'eng plain.
Explanation of Plate II.
PLATE II.

1. View towards west from inside of Lutingshan intrusive, showing easily weathered rock with strong cleavage in the foreground and resistant run in the distance.

2. Iron ore adjoining limestone inlier in Ch'iaoshan.

3. Very strong cleavage in northern part of Ch'iaoshan.
Explanation of Plate III.
PLATE III.

1. Western rim of Lutingshan intrusive.
2. Northern peak of Ch'insuhan from southeast.
3. Ch'insuhan from northwest, showing sediments in foreground.