3. Some Alkaline Rocks of Shansi Province, N. China.

By

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(With Pl. II and III).

Contents.

Preface.

This report is a link in the work carried out by the Nyström Institute for Scientific Research in Shansi. This Institute, which is located in the provincial capital Taiyuanfu and associated with Shansi National University, is cooperating with the Geological Survey in Peking, which institution, during the last ten years or so, has done so much good work in making China better known.

In the preparation of this paper the writer had the privilege of obtaining much valuable advice from dr W. H. WONG, Director of the Survey. The President of Shansi University, Mr L. H. WANG, the Dean of the Engineering Department, Mr H. WANG and the Principal of Shansi Industrial College, Mr S. R. LI have given liberal support by putting books and instruments at the writer's disposal.

The writer also wishes specially to acknowledge the assistance of E. NORIN, M. A. who spent three years (1920—1923) in Shansi and through having visited some of the alkaline areas described in this report was able to offer much valuable advice on the matter in hand. He also helped to organize our Institute and his contributions towards the first years' work have been of fundamental value.

I have also been favoured with much kind advice from Prof. G. B. BARBOUR of Yen Ching University, Peking; Prof. P. D. QUENSEL of Stockholm University and Prof. H. BACKLUND of Uppsala University have been good enough to supply, as far as it has been possible at such distance, advice on literature pertaining to the subject in view. Dr B. ASKLUND and Mr G. BESKOW of Stockholm University have kindly assisted in procuring micro-slides and micro-photos.

My brother, Prof. GUNNAR NYSTRÖM of Uppsala University, has donated instruments for the Institute in general and this investigation in particular.

My assistants Messrs C. C. SUN, S. L. TSAO and K. S. CHANG have drawn several of the maps and diagrams and also helped in the examination of the Lung Wang Miao and other intrusives in S. Shansi.

This paper has been written in the interior of China and many difficulties have been encountered not only because of the scarcity of reference books (scientific libraries in China being still in their infancy), but also because of frequent civil wars which have impeded postal and other communications with the outside world. I should have liked to dwell more fully on the petrographical description, but the abnormal conditions already mentioned have precluded it, and this was also in part the reason why I hesitated to supply new names to some of the rocks described, although these rocks, being at variance with known types, would deserve their specific nomenclature. Another argument in favour of deferring this procedure is the possibility that other areas of alkaline rocks may yet be discovered in Shansi.

The local names of mountains, rivers, villages etc. are rendered in English according to the so-called Post Office romanisation, but scholarship being rare amongst the inhabitants of the Shansi hills, it has often been difficult to ascertain the correct Chinese characters and consequent English equivalent of the various geographical names in use.

The Nyström Institute for Scientific Research in Shansi.

Taiyuanfu, N. China, April 1927.

Introduction.

Shansi province—covering an area of 212054 square km, or equal in size to England and Scotland combined—is situated between lat. 35° and 41° N and long. 111° and 114° E. Its name »Shan Hsi», meaning »West of the Hills», has evidently been given it by the people living on the Chihli plain, to whom the eastern escarpment of the elevated Shansi plateau appears as a long range—the T'ai Hang Shan.

The capital, Taiyuanfu, located 400 km SW of Peking, has about 100000 inhabitants and being connected by railway with Peking and the coast offers a suitable starting point and headquarters for the exploration of the province. Such exploration is also facilitated by the peace and good order kept in Shansi since fifteen years by H. Exc. Governor YEN HSI SHAN.

The province has been subject to geological investigation at a comparatively early date. It was in 1870 and 1871 that Freiherr FERD. VON RICHTHOFEN explored a considerable part of Shansi, his observations being compiled in the second volume of his monumental work »China» (22). W. A. OBRUTSCHEW, in connection with his extensive survey of Mongolia and Kansu, also visited Shansi and contributed much to our knowledge of the province (20). In 1903—1904 BAILEY WILLIS led an expedition entering Shansi from NE, proceeding across Wu T'ai Shan, past Taiyuanfu, S Shansi and westwards. Along the route a very accurate topographical and geological survey was carried out, which ever since has been the model for such work in the province. The report has been published by the Carnegie Institution of Washington D. C. (28). Lately extensive reconnaissance has been carried out by C. C. WANG of the Geological Survey of China whose numerous reports are to be found in the Bulletins of the Geological Survey and the Geological Society of China. Pères E. LICENT and P. TEILHARD DE CHARDIN of the Hoang Ho-Pei Ho Museum in Tientsin have contributed much to our knowledge of Shansi, the former by numerous reconnaissances and the latter by investigations in the SW corner of the province. Detail work within limited areas has also been carried out by J. G. ANDERSSON, who discovered and described the Eocene deposits of Shansi (1), and by members of the Nyström Institute since 1920.

Alkaline rocks were first discovered in Shansi by the writer in 1910 at Hu Yeh Shan in the Chiao Ch'eng district, 65 km W of Taiyuanfu. The same locality was visited in 1914 by Père LICENT who collected a number of specimens which have not as far as I know, been fully described. The important intrusive area of Tzu Chin Shan in westernmost Shansi was visited by the CLARK-SOWERBY expedition and mentioned in their joint publication »Through Shen-Kan» (6), but the true nature of these alkaline rocks was not recognised. The first paper published on alkaline rocks in Shansi was written by E. NORIN who surveyed the Tzu Chin Shan area (17). In latter years several new occurrences of alkaline rocks have been discovered in Shansi and adjacent regions: the Liang Chia P'o intrusive in the P'ing Yang basin by C. C. WANG in 1922, the Lung Wang Miao and Tung T'ai Shan areas by members of Nyström Institute in 1925 and the alkaline rocks of northwestern Ordos by Pères LICENT and TEILHARD DE CHARDIN in 1924.

Before entering upon a description of the Shansi alkaline rock and the tectonic movements to which their origin is due, a short sketch of the stratigraphy and geological history of this part of NE China will be given here.

The oldest rocks of the province is an intensely metamorphosed complex of orthogneisses and schists intruded by granites and basic dykes, which since the days of V. RICHTHOFEN has been distinguished as the *T'ai Shan system* of the Archaean. It has been described by BAILEY WILLIS (28) from Wu T'ai Shan, where he endeavoured to establish its relation to the succeeding Pre-Cambrian formation—the Wu-T'ai system. Outside this region the T'ai Shan formation has rarely been definitely identified in Shansi. When exposed to intense regional metamorphism the Wu-T'aian rocks acquire an appearance strikingly similar to that of the T'ai Shan gneisses. When both formations are not found in close contact, it is often impossible definitely to state the stratigraphical position of the rocks.

In Shansi the rocks of the *Wu-T'ai system* have not as a rule suffered such a powerful metamorphism as the T'ai Shan rocks. Sometimes even very fine primary structures are well preserved, giving the rocks a young appearance. In such a state of preservation the Wu-T'ai formation is met with in the Lin Hsien district at the western margin of the Mo Erh Tung horst.

The Wu T'ai formation has lately been studied in its type locality (Wu-T'ai Shan) by C. C. SUN of the Nyström Institute, who is at present engaged in writing a report entitled »Some Observations on the Oldest Formations in Shansi». From the manuscript kindly put at the writer's disposal the following amended version of BAILEY WILLIS' sequence is given in descending order:

Kuan T'ang Kow Series (WILLIS true Nan Tai group).

Conglomerates, quartzites, phyllites, siliceous marbles and jasper.

Erosion Interval.

Si-Tai Series.

Chlorite-schists and quartzites, which make up the main Wu T'ai Shan range.

Liu Ting Szü Series.

Conglomerates, green phyllites or schists, dark grey slates, crystalline limestones, quartzites.

Erosion Interval.

Pai Yün Szu Series.

White marbles, biotite- and chlorite-schists, quartzites and greenstones.

Shitsui Series.

Arkoses, micaceous quartzites, gneisses and mica-schists.

The total thickness of the Wu-T'ai formation is difficult to estimate but is certainly several thousand m. It corresponds, according to v. RICHTHOFEN and WILLIS, to the Huronian.

The Wu-T'ai Series has been intruded by a coarse-grained granite, sometimes associated with tourmaline-bearing pegmatites.

Separated from this late—or post-Wu-T'aian granite by a weathering breccia the succeeding vast series of ancient sediments, of several thousand m thickness (corresponding to the Torridonian in Europe) was styled by v. RICHTHOFEN the *Sinian* formation and counted by him to the Algonkian. Recent discoveries, however, of fossil organisms in its upper part (*Collenia* sp.) have caused it to be included in the Palaeozoic. The Sinian is represented in Shansi by the following series, beginning with the youngest:

3. Limestones, thin-bedded and cherty, not marine, but deposited in temporary fresh-water or saline lakes (cf. GRABAU 9). This is called the Nank'ou Limestone. Layers of sandstone and shale are found interbedded in the limestone.

2. Effusive diabases and tufaceous beds.

1. A thick complex of continental sediments: multi-coloured shales, red and white sandstones and thick beds of gravel and conglomerates.

The Sinian strata in Shansi are generally dislocated, but have not been exposed to regional metamorphism. In typical development the Sinian is found at the western margin of the Mo Erh Tung horst (W Shansi) and at the SW margin of the Wu-T'ai massif.

The deposition of the Sinian sediments was followed by a period of marked orogenic movements and a time of far-reaching denudation, when the greater part of the sediments was removed.

The succeeding Cambrian sediments have been deposited upon a very extensive peneplain, the exact limits of which are not known. It extended over a great part of central and southern Shansi and also over the area of the present Mo Erh Tung horst. Within the peneplain-area the lowermost beds of the Cambrian — the so-called Mant'o series—generally appear as a pink, scintillating, very fine-grained, quartzitic sandstone of rather constant thickness (80 m) and superimposed on this a thin (10—25 m) bed of maroon-coloured shales with interbedded thin impure limestones. Bottom conglomerate at the base of the Cambrian is often missing.

The Mant'o series is conformably overlaid by a series of marine limestones comprising the Middle and Upper Cambrian and part of the Ordovician. The Middle Cambrian (the »Changhia» limestone) consists of several varieties of grey and frequently oolithic limestone, layers of shale are abundant in its lower part. The Upper Cambrian (the »Ch'aumitien» limestone) is characterized by beds of intraformational (edgewise) limestone-conglomerate (Wurm-Kalk), testifying to shallow water origin (cf. GRABAU, op. cit.) The Ch'aumitien limestone is succeeded, probably disconformably, by the Ordovician, represented by a thick, rather pure limestone called by WILLIS and BLACKWELDER (28) the »Tsinan» limestone from its occurrence near the capital of Shantung. The aggregate thickness of the Cambro-Ordovician limestone has been estimated in W Shansi to be about 1100 m. These sediments are often dislocated, but seldom, — and then only locally — folded.

Owing to the absence of sediments little is known about the history of Shansi during the Silurian and Devonian periods.

After the Ordovician period conditions became widely different in different parts of China (cf. Wong 30). Whilst the north-eastern provinces were at this time already uplifted by epeirogenic movement to form a low land upon which neither erosion nor sedimentation was very active, marine deposition continued in the southwest. N. China received no deposits until Lower Carboniferous time. It is possible (cf. GRABAU op. cit.) that during the Viséen the sea entered the Chinese basin from the west along the Nanshan and Tsing Ling geosynclines, but the present area of Shansi was not invaded before Upper Dinantian time, when a great spread of the sea occurred in the Chinese basin, transgressing as before from the west along the Nanshan geosyncline. It is during this epoch that the so-called Taiyuan series was formed (in central Shansi about 130 m thick).

But this is not a continuous marine series, but rather a succession of marine intercalations (near Taiyuanfu not less than eight in number) between continental beds which are usually coal-bearing (GRABAU op. cit.).

This indicates that during the time in question Shansi suffered a succession of marine invasions with long intervals of continental conditions.

The Taiyuan beds are disconformably succeeded by beds of Permo-Carboniferous age (the Shansi series). They contain only a few marine members. The best known succession of late Palaeozoic beds is that described by NORIN (18) and modified in his paper (19). It was studied by him in central Shansi. Here the Shansi series is about 65 m thick and consists of shales, sandstones and thin coal-seams. In its lower part a marine limestone is found. The Shansi series is succeeded upwards by the two so-called Shihhotse series of about 440 m aggregate thickness, being composed of Permian freshwater sediments, and then comes the Shihchienfeng series of Permian arid sediments, about 700 m thick.

In the Mid-Permian the emergence of Shansi from the sea was definite and no more marine sediments have ever been deposited here since that time. The Chinese continent as a whole was definitely established at the end of the Triassic, but numerous large inland basins were formed during the Jurassic. Here and there conditions were favourable to the flourishing of plant-life, giving rise to Mesozoic coalfields of great importance. The Tatung coal-basin in N Shansi is an example. The Mesozoic and Caenozoic succession in Shansi may be expressed approximately thus:

Jurassic freshwater sediments and arid sandstones .... about 1000 m
Jurassic and post-Jurassic white and greenish clay-sediments
and sandstones .... $>$ 200 m

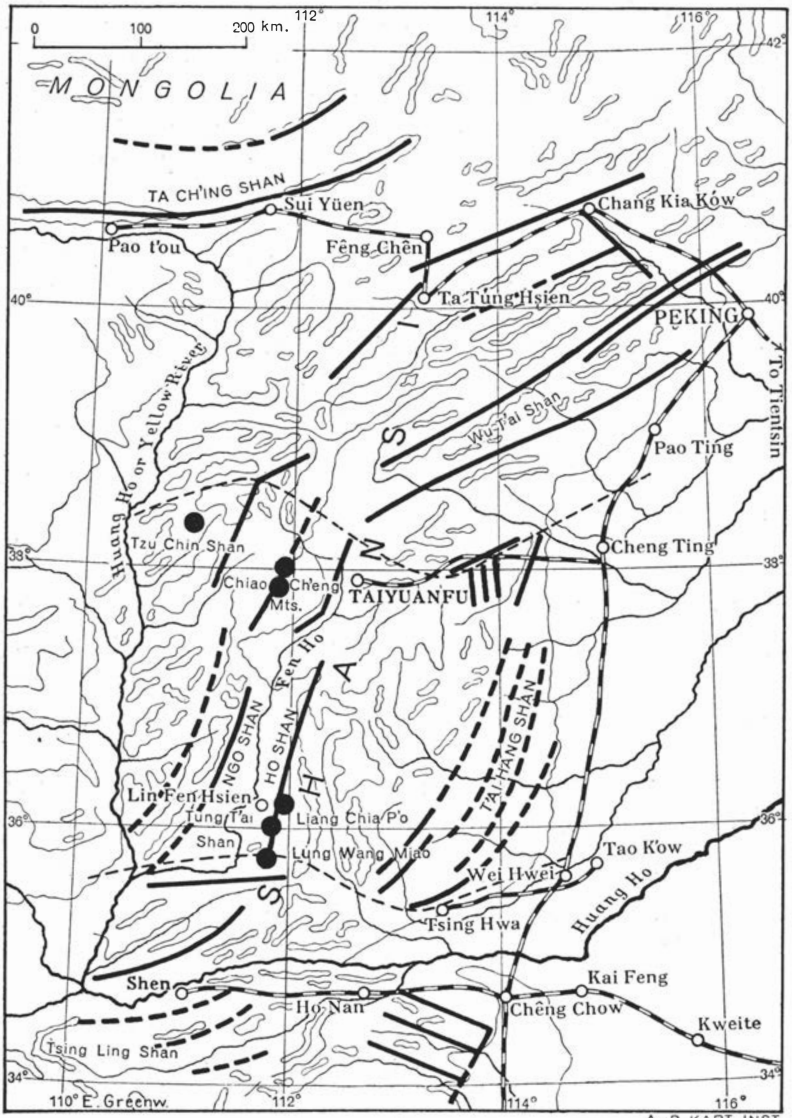
The Jurassic is principally developed at Tatung (see map fig. 1).

Eocene freshwater deposits in S. Shansi (local) .... $\geq$ 1000 m
Pliocene Hipparion-beds, widespread, inconsiderable thickness
Pleistocene loess and associated deposits, widespread .... $<$ 100 m

The following table summarizes the succession of principal formations in Shansi:

Archaeozoic	T'ai Shan Formation
Proterozoic	Wu-T'ai Formation
Palaeozoic	Sinian
	Cambrian, Lower
	Middle
	Upper
	Ordovician, Lower
	Middle
	Carboniferous, Lower
	Permo-Carboniferous
Mesozoic	Jurassic (Liassic)

Caenozoic	Tertiary,	Eocene
		Miocene
		Pliocene
	Quaternary,	Pleistocene
		Human Culture Deposits



Known localities of Alkaline Rocks

Trend Lines

Approximate frontiers of tectonic zones

Fig. 1. Trendlines in Shansi, mostly according to Suess (23).

From a tectonic point of view the province may be divided (see map, fig. 1) in three parts: 1) The zone of folding in NE Shansi, 2) The sedimentary plateaus and the horst-blocks of central Shansi and 3) the N foreland of the Tsing Ling range in southernmost Shansi.

The first zone is tectonically to be considered as a folded block and exhibits a series of parallel folds running from NE to SW and bordering the Mongolian plateau. These are due to tectonic movement during the Jurassic. This block consists mainly of very old rocks, none younger than the Cambrian, except for some *enclaves* of Carboniferous. Of much later date than this folding is a series of faultlines running in the direction of the fold-axes and extending into the area of sedimentary plateaus described below (zone of central Shansi).

The northern foreland of the Tsing Ling range comprises the area between Huangho in the S and the lower course of Fenho in the N (see map). Here old crystalline rocks are predominating with zones of palaeozoic sediments. The folding probably dates from the Mid-Mesozoic. The trendlines which prevail here are influenced by the Tsing Ling Shan tectonics. Compared with the rest of the province this region forms an independent unit. As in the northern folded zone here also a system of young faultlines has split up the block in the direction ENE-WSW. This movement is post-Eocene of age.

Between these folded regions the area of sedimentary plateaus and horst-blocks of central Shansi is situated. The distribution of rocks is determined by a principal system of faultlines running NNE-SSW and another, less marked, running NE-SW. The former is believed to be the older one. Along both directions dislocations have taken place in post-Jurassic time. By the first-mentioned system of faultlines the area in question has been split up in a number of landstrips, each of which has come to form a more or less independent tectonic element. Fig. 2 shows a section through west Shansi between the Yellow River and the Taiyuan basin along lat. 38° according to NORIN (18). The tectonic units are

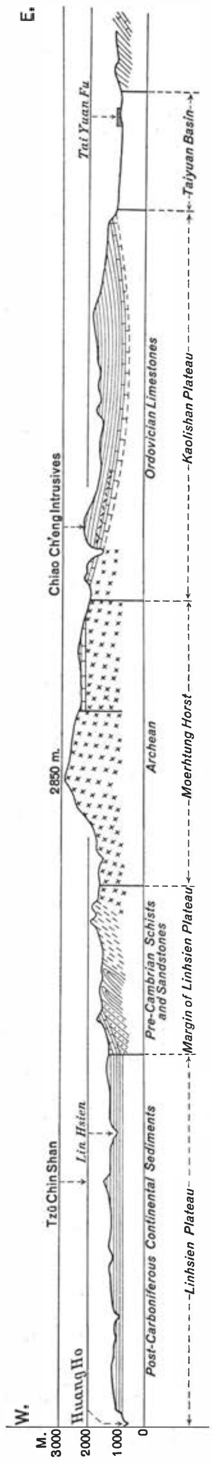


Fig. 2. Section through W. Shansi between the Yellow River and Taiyuanfu.

here represented from W to E by the Mesozoic Lin Hsien plateau, the Archaean Mo Erh Tung horst and the Palaeozoic Kao Li Shan plateau.

The dislocation along the NE-SW system of faultlines have resulted in the formation of a series of depressions extending in the same direction. The Taiyuan basin is the most important of these depressions. At the border between the northern and central tectonic zones in or near the area where the principal faultlines intersect each other, the profound dislocations have resulted in the eruption of alkaline rocks (see map). Thus the Tzu Chin Shan area is situated near the western series of faultlines of the Mo Erh Tung horst, where these lines intersect with the trendlines of the northern grill, and in the same manner the Chiao Ch'eng intrusives appear where the grill-lines encounter the eastern border line of the horst. In the same way we find in S Shansi the Lin Fên intrusives located where the tectonic lines of the Tsing Ling foreland are cut by the trendlines of central Shansi.

As already indicated above there are at present known three areas of alkaline rocks in Shansi. As seen on the map (fig. 1) they are located thus:

1) The central Chiao Ch'eng (Hu Yeh Shan) intrusives about 65 km W of Taiyuanfu. 2) The intrusives 20 to 50 km ESE, SE and SSE of Lin Fên Hsien[1] in S Shansi, 3) Tzu Chin Shan, about 160 km WNW of Taiyuanfu. The description will be given in the same order.

I. The Central Chiao Ch'eng (Hu Yeh Shan) Area.

Location and Topography.

Hu Yeh Shan or Ma An Shan is situated in the centre of Chiao Ch'eng district, W Shansi. It is the most famous mountain in this territory and on its highest eminence, Wang Mu (2384 m) a large cairn is built which is said to be the tomb of Prince Hu Tu of the Chin kingdom (678—376 B. C.). To mark the sanctity of the place a temple has been erected near the top and here every year a fair is held.

Hu Yeh Shan is situated 65 km west of Taiyuanfu. It constitutes the roof of a large lenticular, laccolithic body of syenite, the exposed area of which together with that of some neigbouring satellitic massives attains roughly 48 sq. km. As already indicated the intrusions appear at the western margin of the Kao Li Shan plateau which here adjoins the Mo Erh Tung horst along a wide zone of disturbance.

[1] Old name: P'ing Yang Fu.

On the map, pl. II, the principal topographical and geological features of the intrusive area is shown. To the north, the northwest and west it is limited by the valleys T'un Lan Ho, Nan Szu Tsun and Chiao Ch'eng Ho respectively. To the east and south no marked topographical line indicates the boundary of the intrusives, which here, with a more or less flat dip, disappear below the sediments of the adjoining plateau.

The diagonal valley of Yuan P'ing Kou running in a north-easterly direction separates Hu Yeh Shan from the intrusive massives to the north. The photo fig. 3, shows Hu Yeh Shan as seen from the north. The roof of the laccolith has a slightly undulating surface, roughly 5 sq. km in area the east end of which is marked by a low cone-like eminence called Tung Hsien (2329 m). Apart from this the surface is remarkable flat and unattacked by erosion. This is due to the strong metamorphism to which the covering sediments of the laccolith have been subjected. They belong

Fig. 3. Hu Yeh Shan, view from the north across the valley Yuan P'ing Kou.

to the Permocarboniferous series of shales and sandstones, which by the metamorphism have been transformed into quartzite and hornfels which are more resistant to weathering than the surrounding unmetamorphosed sediments. Thus the laccolith and its sedimentary cover has been left, when the less resistant sediments were eroded away.

The westward slope of Hu Yeh Shan is long and rather precipitous and descends towards the valley of Chiao Ch'eng Ho from which it is separated by a syenitic ridge running approximately N-S and called Nan Yen Shan. Along the northern side of Hu Yeh Shan we descend on a slope of moderate gradient until the subjacent intrusives are met with. Lower down the gradient becomes steeper. The foot of the massif consists of syenitic hills and ridges separated by deep ravines (see fig. 3).

The eastern side of Hu Yeh Shan forms a grasscovered slope, steep at higher levels and more gentle towards the base. It consists of sedimentary rocks dipping eastwards. The southern slope of the massif is strongly eroded and rather precipitous. It consists of sedimentary rocks dipping gently southwards.

The northern massif forms an area of approximately rhombic shape, the longer sides of which run nearly NE-SW or in the main direction of Yuan P'ing Kou (cf. map Pl. II). From the interior of the parallelogram series of remarkably straight ravines emerge, the trend of which conforms in direction with either side of the parallelogram. An exception is formed by the Sui Kung Kou valley, the direction of which is governed by one of the main fault lines of the district. The peculiar arrangement of the local drainage is due to a dual system of fissure lines caused in the massive by tectonic forces and further developed into ravines by erosion. Here no resistant, metamorphosed sedimentary covering has protected the igneous rocks as at Hu Yeh Shan, the smooth and little dissected contour of which is in strong contrast to the topography of the northern area.

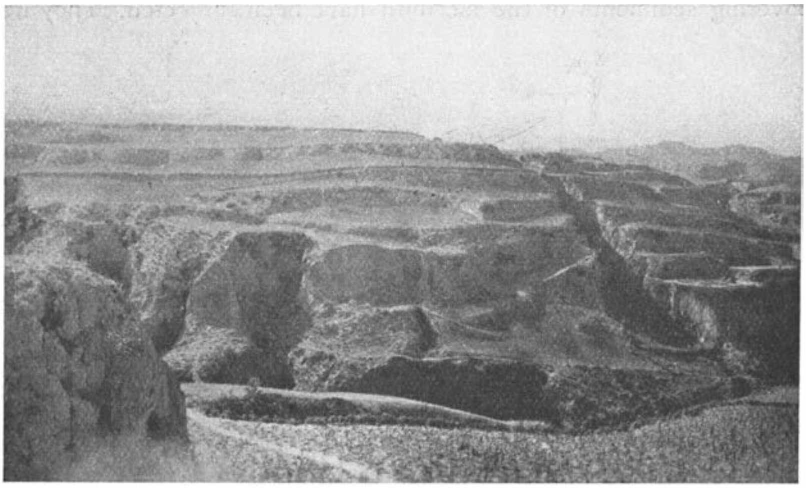


Fig. 4. Loess terraced by cultivation near An Chia Kou at T'un Lan Ho.

The northern massif is dominated by the twin peaks Tung Kuang T'a Men (2281 m) and Hsi Kuang T'a Men (2235 m). Between them is a saddle-like depression from which valleys descend towards NNE and SSW. Tung Kuang T'a Men has a short and gentle slope towards E and is continued by the slightly lower flat ridge Ch'i Huo Ch'i Tung, which runs for about 3 km and then descends gently to the low plateau country further east.

Towards N the northern massif is limited by the broad valley T'un Lan Ho. From the watershed the slope at first descends rather steeply 150—200 m. Then — speaking in a broad sense — it is split up into two lobes, separated by a wide, bay-like indentation of low-lying country. The western lobe which form the N slope of Tung and Hsi Kuang T'a Men consists of long flat limestone ridges which ultimately disappear below the loess of the T'un Lan Ho (fig. 4); the eastern lobe descends by a wood-covered slope of easy gradient and finally passes into a much dissected country of flat limestone hills.

Local sequence of stratification.

Owing to »drag» along the margin of the horst a strip of the borderland has been warped upwards and denuded, thus laying bare older and older formations down to the crystalline fundament. This consists here of Archaean (T'ai Shan) gneisses, amphibolites and schists of various strike and dip, intruded by a coarse-grained Wu-T'aian granite. The Archaean is cut by slightly metamorphosed, often composite dykes of quartz-porphyries and amygdaloid diabases probably of Sinian age. The strike of these dykes is very constant N 70° W.

Fig. 5. Pre-Carboniferous disconformity, 500 m SW of Shang Pai Ch'uan. The cavities have been occupied by iron-ore nodules.

As in many other regions in Shansi the lowest part of the Palaeozoic (the Sinian) is missing here and the crystallines are overlaid directly by the Cambro-Ordovician series. This series consisting from below of pink quartzitic sandstone, maroon Mant'o shale, argillaceous Cambrian limestone, and pure Ordovician limestone coincides well with the standard succession given above (p. 64). The total thickness of this series has been locally estimated to be 1100 m.

Upon the strongly eroded, almost cavernous, ancient surface of the Ordovician lies disconformably the lowermost member of the Taiyuan series (late Lower Carboniferous) which consists of dark red or black shale with nodules of iron-ore (fig. 5). Then follows the coal-bearing formation and succeeding sediments of Permo-Carboniferous age (see p. 65). A section taken along the valley of Shang Pai Ch'uan (see E part of map. pl. II) showed the following composition of these sediments:

The coalbearing series, with an aggregate thickness of nearly 250 m, consists of white sandstones, black shale, a marine limestone and a few coal-seams which are seldom workable. One of the larger seams is worked in the mine in the valley Liu Szu Kou 2 km SSE of Shang Pai Ch'uan[1]. The fauna of the marine limestone is that of the Hsiehtao limestone (cf. NORIN 18) in the Taiyuan area which limestone is characterized by *Pinnatophyllum norini* and *Spirifer bisulcatus*. The sediments belong to the Shansi series of GRABAU (9).

On top of this formation follows the lower Shihhotse series here about 130 m thick and consisting of light green, yellow and grey claystones, shales and sandstones. It is succeeded by the upper Shihhotse series (chocolate-coloured shales and sandstones) more than 600 m thick. The two Shihhotse series belong to Lower Permian.

The youngest semi-solidified or loose detritus deposits consist from below of red clay (Pliocene), loess and associated deposits and recent alluvium. Queer-shaped lime concretions (loess dolls) are typical for the red clay. The loess attains great thickness in the valleys of Yuan P'ing Kou and T'un Lan Ho (see fig. 4).

Tectonics and Favourite Horizons of Intrusion.

Tectonics of the Hu Yeh Shan (central Chiao Ch'eng) area are dominated by the adjacent horst (cf. p. 68) in such a manner that — speaking in a broad sense — the strata show an upwarp or »drag» when approaching the horst. Thus the dips are generally to ESE. But the intrusives themselves have by magmatic pressure caused up-arching of strata in a typical laccolithic manner. Thus the various tectonic features are sometimes the cause, sometimes the effect of intrusions. To obtain a more detailed idea of the tectonics of central Chiao Ch'eng, see map, Pl. II and the subsequent description of the surrounding of the igneous bodies.

The survey of the area has revealed that the intrusions have not taken place in a haphazard manner, but with a decided preference for certain horizons, as illustrated in a schematical way by fig. 6, where the intrusions are represented by arrows, the size of which indicate the magnitude of the intrusions.

[1] This mine is about 30 m deep and has a daily output of about 5 tons. An analysis of the coal was done by the writer and is given below:

Moisture	3,39 %
Volatile Hydrocarbons	4,34 »
Coke (powdery, not cohesive)	92,27 »
Ash (nearly white)	7,16 »
Fixed Carbon	85,11 »

It is an anthracite of rather good quality.

The lowermost of these horizons occurs in the Archaean at a level about 50 m below the Cambrian bottom-conglomerate. There may be still lower intrusions, but these are not visible in our area. The first-named occurrence is particularly noticeable at a point 500 m W of the village Ch'ang Kan Kou (see NW corner of map, Pl. II). Here is a sill about 100 m thick of garnetiferous syenite porphyry which has intruded in the basal crystallines in a position parallel with the superimposed Cambrian sediments. The plane of intrusions does not follow the schistosity of the gneisses, but a series of younger cleavage-planes which extended nearly parallel with the Sub-Cambrian landsurface.

The same magma has also been intruded in the quartzitic Cambrian sandstone and the Mant'o shales forming beds of varying thickness conformable with the bedding plane of the sediments (see sections I to IX fig. 16). The intrusions sometimes chose the upper part of the quartzite, sometimes various levels within the shale, sometimes even the lower horizons of the Cambrian limestone. But, proceeding upwards in the stratigraphical sequence one finds the sills becoming scarce and inconsiderable in size, and in the bulk of sediments, several hundred m thick, which constitute the main part of the Cambrian limestone, intrusions are exceedingly rare.

It is not before approaching the uppermost part of the Ordovician limestone that one of the most important intruded horizons is met with. Wherever the upper part of the Ordovician is cropping out within the area of eruptives, a thick bed of syenite is found, intruded conformably with the sediments, 50—100 m below the top-bed of the limestone. It is a remarkable fact that also in the Lung Wang Miao area in S Shansi the same level of the Ordovician has proved to be a favourite horizon of intrusion for the syenitic magma. Similar observations have also been made by BARBOUR in connection with the investigation of the Tsinan intrusives in Shantung (3).

The explanation may be sought in the fact that the solid and hard Ordovician limestone, in which shaley beds and horizontal cleavages occur rather sparsely, is overlaid with Carboniferous sediments which are mostly soft and pliable. It may be imagined that the magma rising from below along a more or less vertical fissure, opened and widened it, advancing like a wedge driven into a piece of wood, until at a certain level, the pressure of the magma

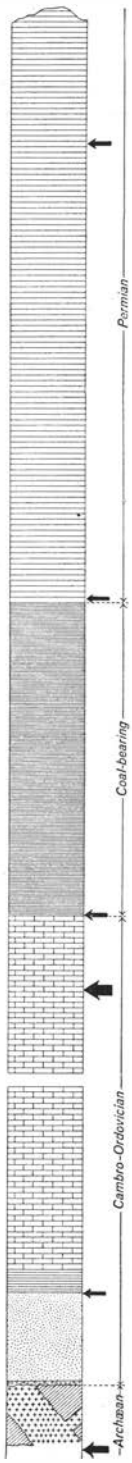


Fig. 6. Favourite horizons of intrusion in central Chiao Ch'eng.

was sufficient to lift the upper limestone beds and squeeze itself in between.

Another favourite horizon of intrusion is the boundary between the Ordovician and the Carboniferous, where owing to the soft and pliable nature of the latter, the magma would naturally like to penetrate. Some of the sills near Lung Ch'uang Kou (centre of map. Pl. II) may serve as example of this.

In the middle and upper part of the coal-bearing formation no igneous sheets habe been found. But proceeding upwards to the lowermost levels of the Shihhotse series (see fig. 6) a rather thin but remarkably constant sill is encountered. Still another intrusive bed occurs in a horizon about 250 m above the lastnamed one. It forms the hill Tung Hsien and the syenitic exposures near Wang Mu on top of Hu Yeh Shan.

The Alkaline Intrusives.

Mode of Occurrence. The alkaline intrusives of central Chiao Ch'eng (of which those of Hu Yeh Shan form the major portion) cover a visible area of 48 sq. km. They appear in rather varying emplacement as laccoliths, stock-like bodies, sills or dykes, intruded in the Archaean or in the sedimentary series as described above. It may be noticed on the map that the sedimentary covering of some of the laccoliths is still preserved, as for example on Hu Yeh Shan whereas other igneous bodies, e. g. the intrusives of the northern massif, are roofless.

The principal intrusives are enumerated below:

1. The large southern laccolith (Hu Yeh Shan).
2. The northeastern chonolithic body (Ch'i Huo Ch'i Tung).
3. The northwestern stocks (Hsi and Tung Kuang T'a Men).
4. The laccolithic remnants on top of Hu Yeh Shan.

From a petrographical point of view the rocks of the two first-named areas show great similarity and are also closely connected in the field. The northwestern stocks with their exceptionally rich association of dykes, occupies a special position not only geologically but also as regards the chemical composition of the rocks. The difference in composition consists mainly in the more pronounced alkalinity of the latter, as revealed by the absence of quartz and the presence of melanite, nosean and sodalite. Thus they remind one of some of the Tzu Chin Shan rocks as described by NORIN (see chapter IV). To the same highly alkaline rocks belong also parts of the laccolithic remnants on top of Hu Yeh Shan.

The large southern laccolith. This large lenticular body of syenite has been intruded in the uppermost part of the Cambro-Ordovician limestone (cf. p. 73). The sedimentary sequence at this place has been described above, see p. 71. The maximum thickness of the sedimentary cover of the laccolith amounts to 300 m and comprises the coal-bearing Permo-Carboniferous and the lower Shihhotse series.

When approaching the village Shang Pai Ch'uan from the east (see E part of map) the horizontal sediments of the Kao Li Shan plateau begin to acquire an easterly or northeasterly dip which at the village amounts to NE 30°. The dip becomes gradually less as we proceed towards SW up the valley and the main part of Hu Yeh Shan, where thick sediments overlie the apex of the laccolith, shows nearly horizontal strata. The general up-arching of strata is evident when coming also from other directions, but this does not preclude the fact that the magma forcing its way from below, has sometimes also fractured the strata resulting here and there in more or less vertical contacts. It seems as already indicated above, that the overlying Carboniferous shale has been specially liable to give way, hence the partial block-faulting produced.

Regarding the lateral extension a glance at the map as well as actual observations in the field point to the fact that this laccolith is not restricted to the SE territory only, but is connected underground with the SW igneous body as well. Petrographical similarity favours also this supposition. It seems that the igneous rock in both territories is really part of one large mass of intrusive which may be sheetlike or laccolithic according to the tectonic facilities offered.

The general aspect of the SE territory is characterized by larger or smaller exposures of the underlying laccolith. As a rule a layer of Ordovician limestone, often partly calcinated by contact metamorphism, forms the innermost covering of the intrusive. This is plainly discernible on the map, where the limestone is seen exposed on the NE and SW slopes of the mountain.

A rather instructive sectional view showing the relation between the intrusive and the limestone, is obtained along the valley which comes from the centre of the mountain and passes Shang Pai Ch'uan. The bottom of this valley which has a gentle gradient from the village upwards for 3 km distance and therefore cuts deeply into the mountain, consists near Shang Pai Ch'uan of coalbearing Carboniferous, and a coalmine or two are sunk in the southeastern brink. Some hundred m up the valley (towards SW) the basement of the Carboniferous is seen and the Pre-Carboniferous disconformity well exposed (see above p. 71). The dip is here NE 20°. The valley bottom still consists of limestone for about 1000 m towards SW. The dip gradually diminishes until it approaches zero and finally the limestone even dips a little towards SW. Then for the first time, the igneous body appears as a cliff of porphyritic åkerite. It joins the nearly horizontal limestone beds along a vertical contact which is strongly brecciated, proving that a faultline separates the formations. Ascending the igneous body and proceeding a few hundred m up the slope one meets again the Ordovician limestone in horizontal or slightly undulating beds. The metamorphism produced by the subjacent intrusive appears mainly as an intense recrystallisation forming a very porous and coarse-grained variety of marble, whereas mineralisation on a considerable scale is seldom observed. Sometimes nests and druses of garnet and iron ore are noticed near the contact, either in the intrusive or in the sediments. The limestone is penetrated by fissures, which are often several dm wide and run in different directions. They are filled by very coarse-grained calcite.

That the emplacement of the laccolith may also be of more regular »text book» shape is proved by investigation along the deeply incised ravine which extends from Shang Pai Ch'uan westwards and terminates near pt 2140 (see map). The contact between the intrusive and the Ordovician limestone is met with at a point about 2 km W of Shang Pai Ch'uan. Here the contact-surface is dipping conformably with the sediments at a moderate angle. The limestone has been transformed into white, crumbling, porous marble. Near the contact it is brecciated indicating that distinct slips have taken place along the contact-surface posterior to the marmorisation.

At both localities above described the intrusive rock is a pink or reddish grey, medium to coarse-grained porphyritic åkerite, sometimes showing miarolithic texture. Inclusions of amphibolite are rather numerous which are often partly resorbed, appearing as rounded dark bluish nodules in the åkerite. These fragments have probably been derived from the Archaean siderock in the deep volcanic channel through which the magma has risen, carrying the fragments with it. A petrographical description of centrally and marginally located samples of the åkerite will be given below (pp. 82—84).

Along the eastern and northeastern margin of Hu Yeh Shan, the Carboniferous forms an »aureole» of varying width. In the northeast where the dip averages 30° the zone is only a few hundred m wide. It is separated from the intrusive body by the aforementioned bank of limestone and the metamorphism noticeable in the latter by the intrusive action soon dies out leaving the Carboniferous unimpaired. Towards the south-east where the dip of the strata decreases, the aureole widens. About one km S of Shang Pai Ch'uan it attains a width of 2 km because here the angle of dip nearly coincides with the gradient of the slope. The Carboniferous beds may be followed to the foot of the Tung Hsien peak and, disappearing here under the Shihhotse beds, they extend westwards and take part in the forming of the laccolith roof.

At the foot of the Shihhotse series a sill of tinguaite porphyry about 10 m thick extends with remarkable constancy at the same horizon all along the eastern slope of Hu Yeh Shan. It was first traced in the neighbourhood of Shang Pai Ch'uan (fig. 7) and, being easily distinguished in the field, is useful as a first orientatation when exploring the stratigraphy of the sediments wrapping the laccolith. Generally the rock which forms this sill is highly decomposed and then of brownish colour with numerous large felspar phenocrysts of platey appearance. This rock, when fresh, is according to NORIN, of greenish colour with dense groundmass in which are scattered large phenocrysts of glass-clear sanidine.

The lower Shihhotse beds form the outer aureole surrounding Hu Yeh Shan towards north and east. Along the foot of the mountain they dip conformably with the underlying Carboniferous at a moderate angle, but eastwards the dip rapidly diminishes until the beds become horizontal and enter into the making of the vast plateau country which borders the intruded area towards E and SE. From the SE a broad lobe of this formation extends up the south-eastern slope of Hu Yeh Shan forming the Tung Hsien peak and extending further west with a width of 1 $^1/_2$ km and a length of 5 km its beds assume nearly horizontal position and form

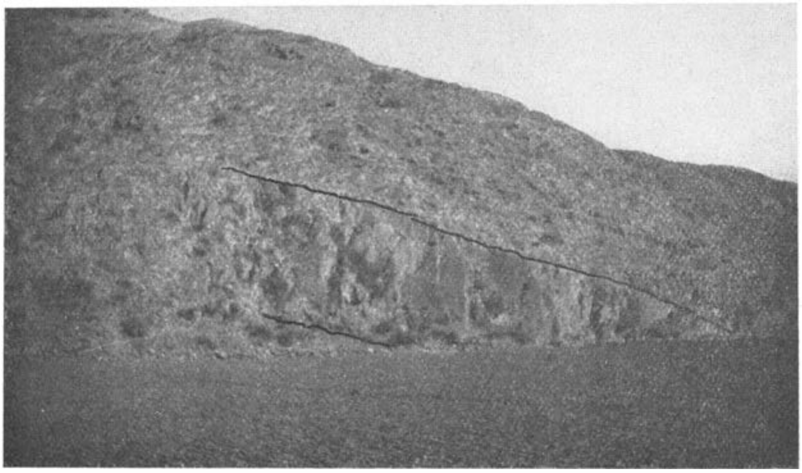


Fig. 7. Tinguaite porphyry sill at Shang Pai Ch'uan (limits marked by black lines).

the slightly undulating plateau crowning Hu Yeh Shan. The most prominent landmark on this elevated plateau is the large cairn Wang Mu. By action of the subjacent intrusive these sediments have been elevated about 500 m in relation to their position in the surrounding area.

To a large extent the surface of this plateau consists of a peculiar rock known only from this locality. It is a dark grey or black, very finegrained to dense rock with scattered crystal aggregates of cordierite. It responds to the hammer with a metallic sound. The microscopical examination shows the rock to be very rich in coaly pigment concentrated in knots and patches (see micro-photo, fig. 8) with small irregular quartz and felspar grains here and there. Cordierite individuals filled by coaly matter and showing triple twinning in sectors are comparatively scarce. The rock may be called a cordierite-hornfels. — Interstratified with the hornfels are found beds of quartzitic sandstone and conglomerate.

A section through the sediments of the Hu Yeh Shan elevated plateau shows that towards lower levels the hornfels grades into the normal yellowish and greyish claystones and sandstones of the Shihhotse series. Below these follows the Carboniferous and then a bank of Ordovician marble of varying thickness. The whole complex is resting upon the åkeritic intrusive and forms the roof of the laccolith.

The fact that the contact-metamorphism produced by the åkerite is restricted practically to a marmorisation of the lower levels of the Ordovician limestone bank only, whereas the Carboniferous and the lower part of the Shihhotse series have been but very little affected, proves that the

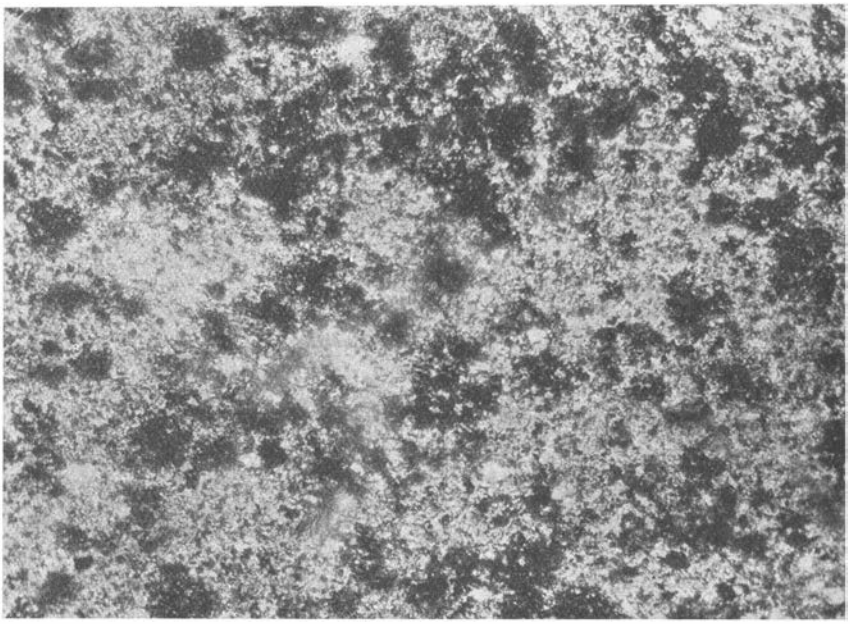


Fig. 8. Micro-photo of hornfels from top of Hu Yeh Shan. ×80, Nic. ∥.

intense contact action represented by the hornfels must have been produced by another intrusive body superimposed upon the latter rock. As relics of this hypothetical high-level laccolith are to be considered the small igneous wedge in Tung Hsien peak and the patch just west of Wang Mu (cf. map and section, Pl. II).

While the slopes of Hu Yeh Shan hitherto described show as a rule normal laccolithic tectonics, the aspect of the northern slope is rather different (cf. section, Pl. II). Here extends, along the valley of Yuan P'ing Kou, in a SW—NE direction, one of the principal faults of the area and this has been instrumental in cutting off and tilting the northern part of the laccolith, which thereby has acquired a dip towards SE of various steepness from 45° to nearly vertical. Thus the southern side of the valley consists principally of outcrops of the main igneous body whereas the northern is composed largely of Carboniferous and Permian.

A large part of the main laccolith has been laid bare by denudation south of Yuan P'ing Kou (see fig. 3, p. 69, where the eroded country at the foot of the mountain denotes exposures of the igneous rock). At the lower levels the outcrops are mostly igneous rocks, at the higher only sediments. 500 m south of Hsiao Lu Fang a thin »Scholle» of Ordovician and Carboniferous sediments has been observed. It is surrounded on three sides by igneous rocks, and to the north it borders on the Yuan P'ing Kou faultline. The sediments dip gently towards NW and their presence may be explained by the fact that part of the laccolith roof has been lowered and preserved by block-faulting; this is clearly seen at the eastern end of the »Scholle» where the sediments are squeezed and contorted in a weird manner.

The Kuo Chia Liang valley which debouches just west of the »Scholle» affords access to the deepest and most centrally located part of the main laccolith. Here one of the principal rock-types (N:o I, sample 172) was collected and it has been petrographically and chemically examined (see below). It is a whitish grey, fairly even- and small-grained abyssic rock of åkeritic composition, plentifully dotted with dark bisilicate crystals. This rock is supposed to be of a composition most closely approaching the parent magma of the region.

The northwestern side of Yuan P'ing Kou consists as mentioned above of a dislocated and tilted block or strip of sedimentary and igneous rocks, which latter may represent the northernmost extension of the large laccolith. The general dip of this block is 45° towards SE. The termination of the laccolith in this direction appears as a series of igneous beds of diminishing thickness (see map). These sills are intruded either in the Carboniferous or the limestone and their outcrops run naturally in the direction of the strike which is here NE—SW. Some of these sills show trachytic character with a rough, porous surface, brick-red colour and true trachytic composition. South of Lung Ch'uan Kou one of these igneous sheets is largely exposed because the dip of the sediments conforms with the general slope of the ground. To the west it is bordered by a small faultline, to the east it disappears below a sheet of Carboniferous sediments which have here acquired an abnormal northeastern dip.

Proceeding up the Yuan P'ing Kou valley towards southwest we arrive at the village Tung T'a which is a suitable place for headquarters. The country hereabout is all Carboniferous characterized to the N by fairly regular strike (NE—SW) but towards the south the sediments are very contorted with irregular and sometimes very steep dips (up to 80°). This is part of the belt of heavily disturbed sediments which mark the SW extension of the Yuan P'ing Kou faultline.

Two km SW and three km SSW of Tung T'a a couple of small, but typical laccoliths have been observed. It is quite likely that they are connected underground. The northern one shows in almost perfect manner the upper part of a laccolithic intrusive and examination is facilitated by the presence of a ravine cutting through both covering and core of the igneous body. Especially to the west and northwest the sediments conform beautifully and here the shoulder of the laccolith is exposed showing characterictic »onion-leaf» cooling planes (see fig. 9, the sedimentary cover is visible in the background). The rock here is the usual pink porphyritic åkerite.

Fig. 9. Shoulder of small laccolith near Tung T'a.

The most conspicuous feature of the region south-west of Hu Yeh Shan is the partly wooded ridge already mentioned above under the name Nan Yen Shan. It runs in a NNE—SSW direction through point 1820 (cf. map) and exhibits a characteristic undulating contour. The rock composition is porphyritic åkerite of the usual pink colour. It was first thought that this was a broad dyke but further exploration ascertained that it is part of a broad laccolithic intrusive. The characteristic rounded emplacement is specially noticeable towards south-west near village Hsi-Yeh. Also the usual belt of limestone and Carboniferous is typically exhibited, every-where with a moderate outward dip. Some coalmines are worked in this belt and also in the low country towards south. The topography is developed in ridges and valleys running in the usual trend-line direction of NNE—SSW. Judging from petrographical similarity it is not unlikely that the Nan Yen Shan intrusive forms part of the main Hu Yeh Shan laccolith.

All the rocks of the intrusives above described, though the may be collected far apart, yet show distinct relationship. They are characterized in handspecimens by pink or whitish colour, medium grain and mostly porphyritic structure. Specimens from the central part of the

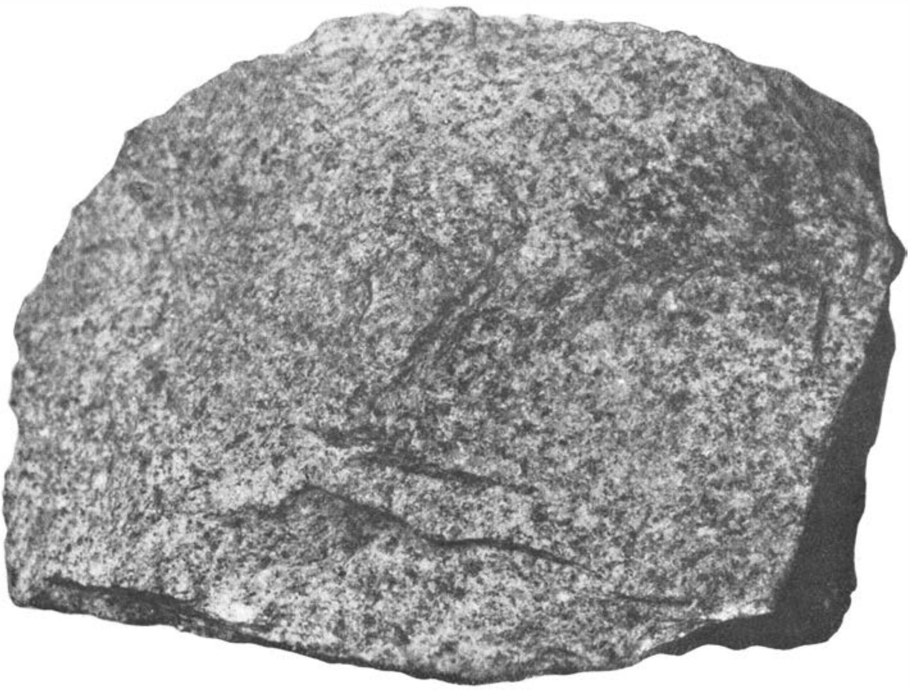


Fig. 10. Åkerite N:o I (sample 172) Hu Yeh Shan laccolith.

large laccolith show as a rule abyssic structure and light grey colour, whereas the marginal facies near the sedimentary roof shows plainly porphyritic rocks with large, whitish grey phenocrysts in an exceedingly finegrained, almost dense groundmass of pink colour. A most remarkable fact is the absence of intraformational dykes within the laccolithic body, this in contrast to the north-western massif which is penetrated by dykes in all directions (see below, p. 93).

A rock specimen (N:o I, sample 172) considered typical of the main mass of the great laccolith has been collected in the valley 1 km NE of village Kuo Chia Liang (cf. map). It is a whitish grey rock, small grained and only slightly porphyritic with very scarce phenocrysts of felspar up to 3×12 mm in size. Small black crystals of bisilicates are plentifully scattered throughout (fig. 10). It shows deep weathering of whitish colour.

Under the microscope the rock is seen to consist of larger idiomorphic plagioclase crystals lying in a somewhat more finegrained groundmass of lath-shaped microperthitic felspars.

The plagioclases mentioned show strong zonary structure with a core of andesine ($Ab_{60}\ A_{40}$) and envelope merging into oligoclase-albite ($Ab_{80}\ A_{20}$). The plagioclases are often twinned according to the albite, pericline and Karlsbad laws and exhibit abundant good sections for optical determination. The alkali felspars show frequent twinning according

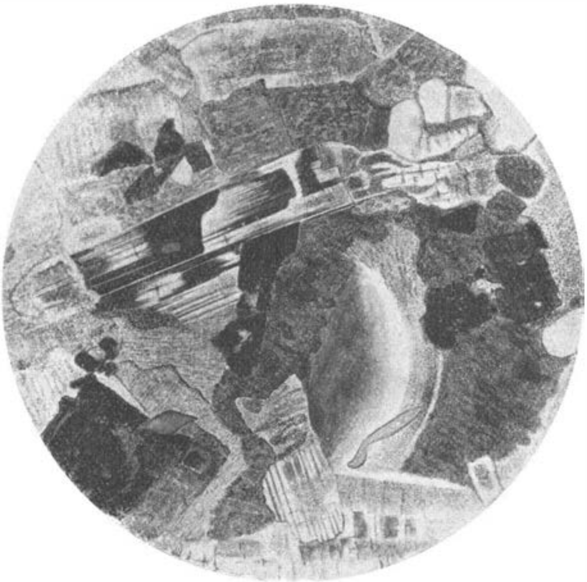


Fig. 11. Åkerite (N:o 1, sample 172) from Hu Yeh Shan. ×30, Nic. +. Drawing by C. C. Sun, S. L. Tsao and K. S. Chang.

to the Karlsbad law and nearly universally a delicate micro-perthitic structure. Abundant small idiomorphic inclusions of an acid plagioclase are seen. The lathshaped alkali felspars show inclination to sub-parallel arrangement. They show the characteristics of the orthoclase-microperthite, common in alkali-syenites.

The plagioclase crystals are often altered by sericitisation, especially in their central parts and so is also the main mass of the alkalifelspar crystals (but not the albite strings).

The femic minerals, estimated to about 5 % of the whole, consist of pyroxene and isolated grains of hornblende. The pyroxene is a light green diopside with small content of the aegirine molecule observable in certain crystals in patches of deeper green colouring and smaller extinction angle (c : X).

The scarce crystals of amphibole detected in the slice show pleochroism on the basis in impure yellow and brownish olive green. No longitudinal section was seen. The amphibole has evidently been liable to decomposition, several grains showing the characteristic outline, but containing now only a mass of chlorite and limonite.

A little quartz exists as final product of crystallisation. The accessory minerals are: abundant sphene, often showing polysynthetic twinning, zircon, apatite and magnetite.

The drawing, fig. 11, gives an idea of the general microscopic appearance of the rock. The chemical composition is shown by the following analysis and calculations:

Table I. Analysis of åkerite from outcrop in valley, 1 km NE of Kuo Chia Liang village in central Chiao Ch'eng district. Analyst: Dr N. SAHLBOM.

S. G. — 2,64 (E. T. NYSTRÖM).

Analysis I		Mol. Prop.	Norm		NIGGLI's System[1]	
SiO_2	60,78	1013	Qu	4,56 %	qz	— 2
Al_2O_3	15,39	151	Or	27,24	si'	212
Fe_2O_3	4,21	26	Ab	45,02	si	210
FeO	1,70	24	An	4,45	al	31,3
MgO	0,95	24	Σ sal	81,27	fm	21,3
CaO	5,25	94	$CaSiO_3$	8,24	c	19,4
Na_2O	5,32	86	$MgSiO_3$	2,40	alk	28,0
K_2O	4,56	49	Mt	4,64	k	0,36
H_2O	0,40	22	Hem	0,96	mg	0,23
TiO_2	0,50	6	Ilm	0,91	ti	1,3
P_2O_5	0,31	2	Ap	0,67	p	0,4
MnO	0,17	2	Σ fem	17,82		
	99,54		H_2O	0,40		
				99,49		
Moisture	0,26					

Quantitative System: II : 5 : I : 4 — *Umptekose*

OSANN's System:	s	A	C	F	a	c	f	n	k
	68,0	9,0	1,0	12,0	8,2	1	10,8	6,3	1

Or : Ab : An — 35,5 : 58,7 : 5,8; MgO : CaO : FeO — 25,2 : 74,7 : 0

[1] Amongst various attempts diagrammatically to represent the composition of rocks and their differentiation, the system of P. NIGGLI, first rather largely expounded in P. NIGGLI and P. J. BEGER (16), seems to possess the advantage of simplicity and lucidity. The diagram for each rock is constructed thus: Find the molecular proportions from the analysis (all Fe as FeO), then recalculate: 1) Al_2O_3, 2) (Fe, Mn)O plus MgO, 3) CaO and 4) K_2O plus Na_2O to the sum of 100 and call these four groups al, fm, c and alk respectively. Thus al + fm + c + alk equal to 100. The silica figure si is obtained thus: Mol. prop. of SiO_2 : Mol. prop. of Al_2O_3 equal to x:al, and in the same manner ti,

The analysis shows a rock of medium acidity, rather femic, at least in comparison with other local rocks, and highly felspathic. Some »hematite» of the norm may enter in the pyroxene as trivalent iron. The alumina is not sufficient to form as much anorthite as would seem to be present in the mode. It may be that part of the Na_2O should from the acmite molecule $Na_2O . Fe_2O_3 . 4 SiO_2$, thus leaving more alumina free to form anorthite. Here as elsewhere the frequent discrepancy between norm and mode is apparent.

Both the analysis and the microscopic determination of the mineral composition classify the rock as an alkali-syenite intermediate between monzonite and åkerite. By certain arguments later to be elucidated, this

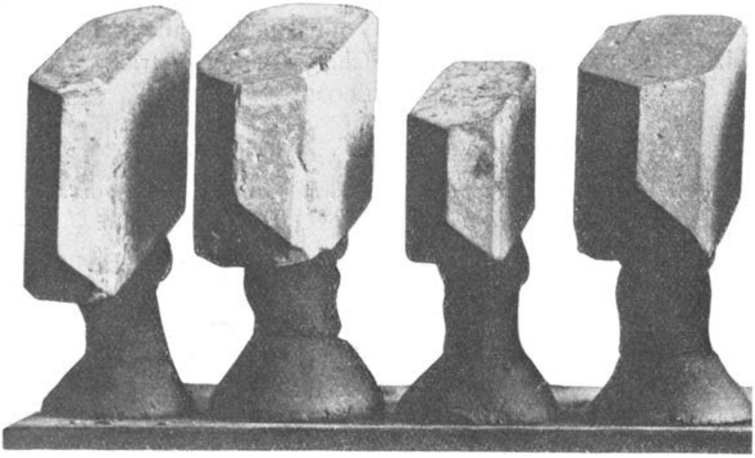


Fig. 12. Orthoclase crystals (natural size) from Yueh Fang Kou, 1 1/2 km SW of Shang Pai Ch'uan.

rock is considered to be the parent rock of the other intrusives. It is similar to the åkerite porphyry of Tzu Chin Shan in west Shansi and still more like the åkerite of Lung Wang Miao intrusive in south Shansi, both supposed to approach the parent rock of their respective districts.

Towards the contact with the sediments the rock, as mentioned above, becomes more plainly porphyritic with a dense groundmass and phenocrysts up to 10 mm in size. The mineral composition is the same as in the central part, but sphene and quartz are very scarce. In the small ravine Yueh Fang Kou, 1 1/2 km southwest of Shang Pai Ch'uan (see p. 75) this marginal facies contains pegmatitic »Schlieren» with large and well-developed orthoclase crystals which often occur weathered out on the ground (fig. 12).

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p, h etc. Mol. prop. of K_2O to sum of alkalis is k and mol. prop. of MgO to sum of FeO, MnO, MgO is mg. si' is equal to 100 plus 4 alk and qz (the quartz figure) is si minus si'.

The contact action of this large laccolithic body is not so extensive as might be expected. The limestone, which in most places forms the immediate cover, has been transformed in a sometimes porous, sometimes more solid yellowish or white marble. The metamorphism seldom penetrates more than one or two m into the sediments. Besides thermal action the magma seems to have produced a certain amount of gaseous matter (*agents minéralisateurs*) judging from the presence of contact minerals, especially near the supposed apex of the laccolith (see below).

To the very last stages of metamorphism is to be reckoned the alteration which the igneous rock itself has suffered near the sedimentary contact. Thus it is often seen that the syenite, to a distance of a few m from the contact, has been strongly kaolinised, forming an earthy white mass. This is ascribed to post-igneous, hydrothermal action. It is specially noticeable in the valley west of Shang Pai Ch'uan and west of Hsiao Lu Fang.

Owing to the intense kaolinisation to which the marginal parts have been subjected it is often exceedingly difficult exactly to locate the actual contact surface between eruptive rock and sediment. In this soft crumbling mass contact minerals are not easily found *in situ*. It is however notable that in the upper part of the ravines originating near the supposed apex of the laccolith, contact minerals are rather abundantly found amongst the gravel. They consist of large crystals and crystal aggregates of brown garnet, hematite, vesuvianite and rock crystal. The topography proves that these minerals must have originated in the contact zone abovementioned.

One of the rare instances where a sharp contact has been observed is at the small isolated patch of sediments 4 km west of Shang Pai Ch'uan. The åkerite here is of a coarse porphyritic type and only slightly kaolinised. It is overlaid by the Ordovician limestone which has been transformed into a yellowish white, coarse-grained marble traversed by numerous veins of calcite. No other contact minerals were observed here.

The north-eastern chonolithic[1] body (Ch'i Huo Ch'i Tung). As plainly to be seen on the map, the area north and north-west of the large southern laccolith is very strongly disturbed by tectonic movements. As a rule the strata show here a strong and uniform dip towards south-east. The boundary between the two areas follows the valley of Yuan P'ing Kou. A narrow belt of Carboniferous follows the north side of the valley. At village Mu Lung P'o it swings northwards to Hsi Sheng Kou and at the same time the dip assumes a smaller angle. The Carboniferous is as usual underlaid by the Ordovician limestone, having the same dip.

The area between Yuan P'ing Kou and T'un Lan Ho is occupied by two large blocks of Cambro-Ordovican limestone, separated by a faultline running NNE—SSW along the valley Sui Kung Kou (see N part of map).

[1] Chonolith, cf. R. A. DALY (7), is a collective name for intrusive bodies which are neither laccoliths, stocks, or sills.

Each block as a whole has been tilted 20°—45° towards ESE. Thus along the escarpment of Ma An Ch'iu and further SSW to the pass between Tung Kuang T'a Men and Ch'i Huo Ch'i Tung the Cambrian quartzite which underlies the eastern block can be traced. At the pass it adjoins, along the faultline, the Ordovician limestone of the western block.

Near the boundary between the Carboniferous and the Ordovician of the eastern block a series of syenitic sills has been intruded conformably with the sediments. These sills sometimes unite and form larger bodies, as for instance north-west of Lung Ch'uang Kou. They may be followed as far north as the lower course of Hsi Sheng Kou at the north-east corner of the mapped area.

The largest intrusive however in the eastern block is the important massif of Ch'i Huo Ch'i Tung. It is a chonolithic body occupying an area of approximately 7 sq. km. Towards east it adjoins the sediments almost conformably with the dip of the strata, but in other directions it is limited by more or less vertical contacts.

Characteristic for the north-eastern body is the presence of large strips of Ordovician limestone inside the igneous massif. They are apparently more or less vertically placed and may therefore be called »inliers» to use an American expression (cf. WANDKE 26). They sometimes attain a length of 1 km or more and a width of nearly 100 m. These strips proceed in the normal strike direction (NNE—SSW) and consist of limestone which has been transformed into yellow, crumbling marble. When proceeding along the highest ridge of Ch'i Huo Ch'i Tung which runs very sinuously in a general W—E direction, one passes two of the larger inliers; they appear as saddle-like depressions in the ridge.

Concerning the sequence of eruption, the fieldwork leads one to assume a slight difference in age between the intrusions of the above-mentioned sills and the chonolithic body. The sills evidently belong to the same intrusive period as that of the Hu Yeh Shan laccolith, whereas the chonolithic massif seems to cut across not only the sediments but also the sills. The composition of the latter as represented by a specimen collected 1 km north of Lung Ch'uang Kou shows the characteristics of an åkerite porphyry. It is a rock of light lilac-tinged, pink colour and with dense groundmass, here and there miarolithic, and with glassy looking and white felspar phenocrysts up to 3 × 5 mm in size. They are seen under the microscope to consist of andesine, generally showing a sharp rim of potash felspar. The groundmass consists of alkali felspar and some interstitial quartz and magnetite.

The principal rock of the massif Ch'i Huo Ch'i Tung (N:o II, sample 170) is of very light, pinkish grey colour and porphyritic texture (fig. 13). The groundmass is sometimes slightly miarolithic. Under the microscope

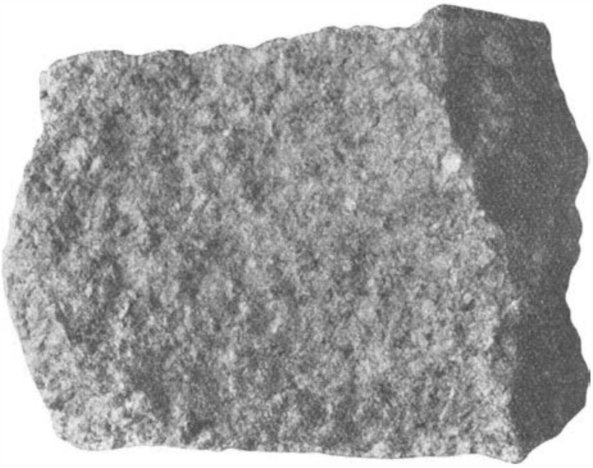

Fig. 13. Nordmarkite porphyry (No. II, sample 170) from Ch'i Huo Ch'i Tung (1 : 1).

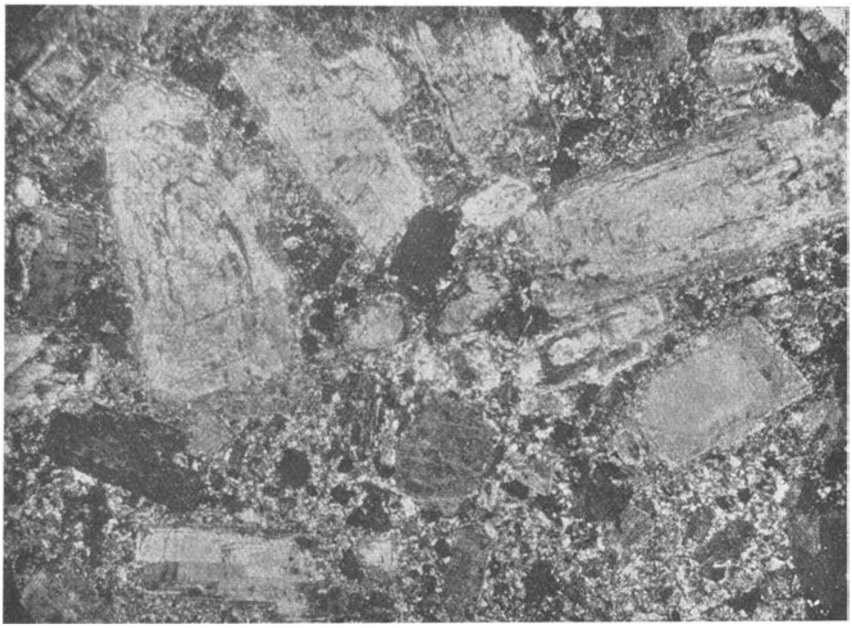

Fig. 14. Nordmarkite porphyry, × 11,5, Nic. + from C'hi Huo Ch'i Tung.

(fig. 14) are seen large, idiomorphic, closely packed phenocrysts of felspar (up to 4 × 8 mm in size) and scattered bisilicate minerals in a finegrained felspathic groundmass in which dark minerals occur sparsely. The phenocrysts are: a perfectly twinned zonary plagioclase (fig. 15) with centre of acid oligoclase ($Ab_{85}An_{15}$) and shell of albite; a sometimes perthitic potash felspar with occasional inclusions of plagioclase crystals; a brownish green

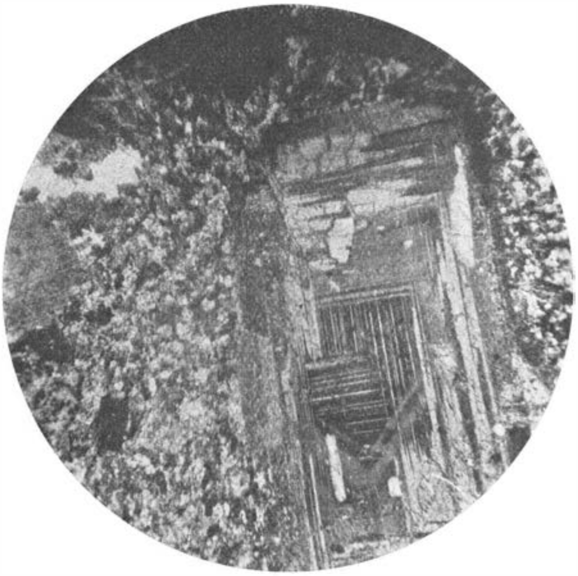

Fig. 15. Plagioclase phenocryst (× 100, Nic. +) in nordmarkite porphyry from Ch'i Huo Ch'i Tung.

hornblende and short prisms of aegirine-augite. The groundmass consists of potash felspar and some interstitial quartz. The accessories are sphene and magnetite.

The chemical character of the rock is shown by the following analysis:

Table 2. Analysis of nordmarkite-porphyry from Ch'i Huo Ch'i Tung, central Chiao Ch'eng, by N. SAHLBOM.

S. G. — 2,56 (E. T. NYSTRÖM).

Analysis II		Mol. Prop.	Norm		NIGGLI's System	
SiO_2	64,15 %	1069	Qu	5,10	qz	13
Al_3O_3	17,90	175	Or	25,02	si'	244
Fe_2O_3	2,07	13	Ab	56,07	si	257
FeO	0,74	10	An	6,39	al	42
MgO	0,38	10	Σ sal	92,58	fm	11
CaO	2,56	46	$CaSiO_3$	1,86	c	11
Na_2O	6,66	107	$MgSiO_3$	1,00	alk	36
K_2O	4,20	45	Ilm	0,91	k	0,30
H_2O	0,39	22	Mt	1,16	mg	0,21
TiO_2	0,45	6	Hem	1,28	ti	1,4
P_2O_5	0,35	2	Ap	0,67	p	0,5
MnO	0,06	1	Σ fem	6,88		
	99,91		H_2O	0,39		
Moisture	0,19.			99,85		

Quantitative System — 1 : 5 : 2 : 4 — *Laurvikose*

OSANN's System:	s	A	C	F	a	c	f	n	k
	71,48	10,2	1,4	4,7	12,5	1,7	5,8	7,1	1,04

Or : Ab : An — 28,6 : 64,1 : 7,3; MgO : CaO : FeO — 38,4 : 61,6 : 0

The mineral composition as well as the chemical analysis classifies the rock as a sodic alkali-syenite, which it might be appropriate to call a nordmarkite porphyry. For further discussion see chap. V.

The northwestern stock. In the same manner as the intrusive mass of Ch'i Huo Ch'i Tung appears in the eastern block we find in the western block the syenitic massif of Tung and Hsi Kuang T'a Men. At the pass where the Sui Kung Kou fault-zone cuts across the area, the block consists of Ordovician limestone dipping steeply towards SE. Proceeding NW one encounters lower and lower strata of the Ordovician and Cambrian untill finally, when approaching Ch'a K'ou the Cambrian quartzitic sandstone and its Archaean foundation are met with (cf. section, Pl. II). Towards N and NW the block is limited by faultlines along the Nan Szu Tsun and T'un Lan Ho valleys.

Leaving the large village Ch'a K'ou in the NW corner of the mapped area and proceeding SSE we meet the first solid outcrops at a distance of 3 km. They consist of a much broken-up system of strips of Cambrian quartzite and limestone with many syenite porphyry sills. The map indicates incompletely the chaotic tectonics of this area with its step-faults, drag of strata along faultlines, etc.; also through the partial covering of loess the geology here offers considerable difficulties to unravel.

Proceeding east towards the village Ch'ang Kan Kou the ordinary NNE-SSW strike is maintained with dips towards ESE of 25° or thereabout. Near the west end of the village the contact between the Cambrian and the Archaean is beautifully exposed, the bottom-conglomerate of the former being well visible. Below this comes 50 m of crystallines and then a thick sill-like body of melanite-bearing syenite porphyry, which shows distinct relationship to the main northwestern stock.

NNE along the riverbed that runs past Ch'ang Kan Kou the Cambrian sediments are well exposed on the eastern brink. Here in the transitions between quartzite, shale and limestone there is a specially clear exhibition of the intrusive manner of sills. This has been pictured in a series of sections at measured distances from north to south, the profiles taken from the valley bottom upwards (see map. Pl. II and fig. 16, sections I—IX).

Starting at a point 1 km NE of Ch'ang Kan Kou we notice that the eastern side of the river shows at the bottom a slope of loess and above that a small outcrop of the Cambrian quartzite, unintruded, and dipping normally 25° to ESE. Above this comes conformably a layer of 10 m of maroon shales also unintruded, then comes the Cambrian limestone (here oolithic). 40 m of this is normal and unintruded, but above comes a

12 m sill of syenite porphyry intruded conformably with the limestone strata. The porphyry is of brown colour with thin felspar phenocrysts of tabular shape max. 2 cm long and 2 mm thick. Above this sill the limestone continues without further intrusions.

Proceeding to SSW there is only need to go 140 m, before the conditions of intrusion have changed as far as the horizon concerns. Here section II was taken. The same series of sediments exists, but the por-

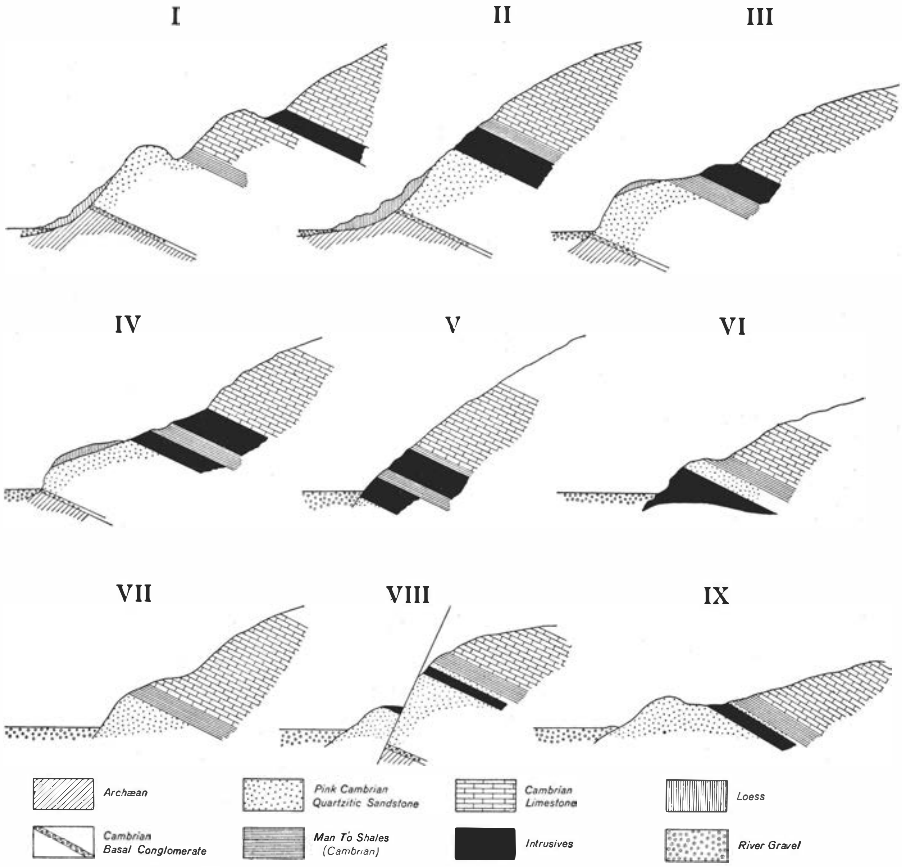

Fig. 16. Intruded sediments at Ch'ang Kan Kou.

phyry now intrudes between the quartzite and the shale and is thicker (20 m). The shale has been bodily pushed upwards as its thickness is nearly the same as before (11 m).

Already 60 m SSW of this section the sill climbs up to a still higher level and in section III (80 m SSW of section II) 20 m of porphyry is found at the top of the shale between this and the limestone. Shale is still 11 m and porphyry 20 m as before.

In section IV, which is 150 m SSW of III, the intrusive has split up in two sills, one below and one above the shale, which latter still maintains its thickness of 11 m. The lower porphyry is 12 m, the upper 18 m, showing a total thickness, larger than above, by 50 %.

Section V, 50 m SSW of IV, shows somewhat different feature inasmuch that the upper sill actually invades the shale leaving 3 m of this on top and 8 m below, the sill itself being 20 m. Between the base of the shale and the quartzite there is another sill of 12 m.

In section VI, 70 m SSW of V, the shale is left unimpaired and the porphyry intrudes right into the quartzite, leaving 10 m of the latter above itself.

In section VII, 30 m SSE of the last one, the porphyry which is still inside the quartzite, disappears out of sight below the riverbed.

Section VIII, 80 m S of section VII, is interesting inasmuch that it shows one of the numerous post-igneous faults present in this territory and this one like most of the others has a strike of NNE—SSW. This small fault the throw of which is only 15 m, is well exposed in a water-worn ravine and shows a fine slicken-side. From above we find in this ravine: limestone, shale (11 m), quartzite (3 m), porphyry (5 m), quartzite (13 m), porphyry (repetition of above, 5 m), then quartzite right down to the main riverbed. There is only one sill which has been repeated by the fault.

The ninth and last section which brings us up to within 300 m of Ch'ang Kan Kou, is 200 m S of section VIII. It shows the same sill as in VIII, but being east of the faultline it does not show such a break. The porphyry is here 8 m thick and lies in the quartzite 2 m below its roof. Shale and limestone are not invaded. Dip is here 30° to SE. The shale is still normally 11 m thick.

The intrusive features revealed in these nine sections show the extraordinary mobility and fluid nature of the magma. It seems to have searched everywhere for the path of least resistance and while the shale horizon has naturally been preferred, yet the quartzite which is also well stratified has not been exempted from intrusion. That the limestone is affected only in section I may be caused by the fact that the magma, rising from below, has first found the more easily intruded formations and rarely reached the limestone.

One of these sections (VIII) shows conclusively that the intruded sediments have been dislocated also *after* the intrusion and solidification of the magma. This is still more clearly revealed at the NW corner of the district near Ch'a K'ou (cf. p. 89) where a whole series of post-igneous stepfaults is to be found (cf. section Pl. II).

Speaking in a broader sense, it is however certain that important faultlines occur in the northwestern area which are *older* than the main intrusions of Hsi and Tung Kuang T'a Men. This applies specially to the important zone of faults roughly 1 km wide, the eastern boundary of which is marked by the Sui Kung Kou valley. The pre-intrusive age of these faults is proved by the fact that the very conspicuous friction breccias which traverse the archaean west of Sui Kung Kou in the general NNE—SSW trendline direction, do not penetrate into the intrusive body. A further proof is furnished by the small dykes which extend in the direction of the faultline in the zone in question, and one of which is visible on the map one km S of An Chia Kou. In this case the fissure must have antedated or been simultaneous with the intrusion.

On the other hand it is highly probable that the Sui Kung Kou fault-system is simultaneous with that large faultline which extends along the Yuan P'ing Kou valley (see p. 78) and along which the northern part of the Hu Yeh Shan laccolith was broken off. Thus the Yuan P'ing Kou fault is posterior to the intrusion of the Hu Yeh Shan laccolith.

The Yuan P'ing Kou and Sui Kung Kou faultlines represent the SE and NW boundary lines of one and the same tilted block (which contains the Ch'i Huo Ch'i Tung intrusive). The conclusions may therefore be arrived at with some certainty that also the Sui Kung Kou faultline is younger than the Hu Yeh Shan laccolith.

The main intrusive massif of the northwestern territory occupies a heart-shaped area about 10 sq. km in size. The shape is rather similar to the Ch'i Huo Ch'i Tung intrusive and the two areas are orientated very much in the same way (see map). The field-observations at the margin of the NW massif has revealed a stock-like emplacement and from the stock »tongues» project into the surrounding Archaean and sediments. Some distance away from the margin numerous dykes are seen which sometimes are running parallel with the contour of the massif, but often cut through in other directions. To this system of minor intrusives the numerous sills at Ch'ang Kan Kou (described above) may also be counted.

At a distance of one km south of this village the contact between the limestone and the main intrusive is well exposed. The contact is nearly vertical. Within a zone some 10 m wide the limestone, being the argillaceous Cambrian type, is transformed to impure yellow marble. A small dike lies inside the limestone near the margin. Just east of here the main Sui Kung Kou faultline proceeds, marked by a steep escarpment running very straight NNE--SSW (see map). A small syenitic dike, mentioned above, accompanies it for some distance in a manner typefying the origin of its existence.

To the east the massif is bordered by the Archaean area of Sui Kung Kou, which, in the shape of a narrow wedge, penetrates into the mountain along the main faultline. The part of the igneous massif which cuts across the faultline is elongated towards SSW along the same line. The igneous rock has not taken part in those movements which dislocated the sediments but has been intruded at a later stage. The SW frontier of the massif proceeds entirely in limestone. This is sometimes warped upwards, but very often there is nearly vertical, abutting contact, standing at 70° or 80°. Scattered dykes accompany the margin but they do not always follow the contour. Towards west we find a crop of dykes running irregularly in many directions. Such a dyke runs almost E—W just across the temple-crowned pass Shu T'ou Ling (pt 1883).

Just as in Ch'i Huo Ch'i Tung inliers of sedimentary and Archaean rocks exist also in the northwestern territory. Those towards SW are very small and rounded (not shown on map) and may be roof-pendants, but those in the centre and towards SE appear as strips of some magnitude elongated along the general direction of strike, i. e. NNE—SSW. They are remains of foliae between which the magma was pressed up.

A characteristic feature of the northwestern massif as compared with the southern one, is the occurrence of swarms of dykes which penetrate the main body. Nor is the rock composition of the latter as uniform as in the Hu Yeh Shan laccolith, but exhibits a variety of types.

Somewhat west of the peak Tung Kuang T'a Men and a little north of Hsi Kuang T'a Men peak lie the centres of two areas the rocks of which show decided abyssic nature. These two areas are not large, perhaps $^1/_2$ sq. km each. The mode of occurrence as well as petrographical evidence indicate that these areas represent two distinct channels of eruption separated at lower levels by a wall of Archaean, part of which is visible as the inlier half way between the two peaks.

Towards the margin and also towards the saddle-like depression between the two peaks the bulk of the syenite becomes very porphyritic with large phenocrysts. It very often changes colour from grey to reddish or brown where the margin is limestone, but not so when it is Archaean. It seems that the Carbonic Acid given off from the limestone by the heat of the magma has penetrated some distance into the igneous rock and caused oxidation of the bivalent iron-content of the felspar to trivalent iron, which gives the reddish colour (v. ECKERMANN 8, p. 481), This phenomenon is so universal that it is often possible to know when the margin is approached from the inside just by the appearance of the reddish colour in the eruptive rock.

A type specimen from the Tung Kuang T'a Men area has the following appearance: A bright, bluish grey, finegrained rock with small dark prisms of bisilicates. Whitish weathering. Under the microscope the rock is seen to be a hypidiomorphic, rather even-grained syenite, consisting mainly of alkali-felspar, pyroxene, ore-grains, a not inconsiderable quantity of sphene, a little biotite and apatite and an isotropic mineral.

The felspars are a sodium-bearing orthoclase and, subordinately, acid plagioclase. They appear partly as granular, partly lathshaped crystals with jagged contour. The pyroxene inclines towards aegirine-augite with pleochroism between pale green and wine yellow and is more aegirinic than in the southern laccolith; extinction $c : X = 40°$. Magnetite occurs rather plentifully in large irregular grains, about equal in quantity with the pyroxene (about 2 %). The sphene is slightly pleochroic, idiomorphic and often developed in large wedge-shaped crystals. The isotropic mineral is probably sodalite.

The principal rock of Hsi Kuang T'a Men is identical with that of Tung Kuang T'a Men, but is perhaps more alkaline. The pyroxene has a more pronounced zonary structure with darker green rim.

Closely related to these rocks is N:o III sample 176, collected 500 m NNE of Hsi Kuang T'a Men, this type extends from here towards pt. 2008. On account of heavy covering of debris it was not possible to

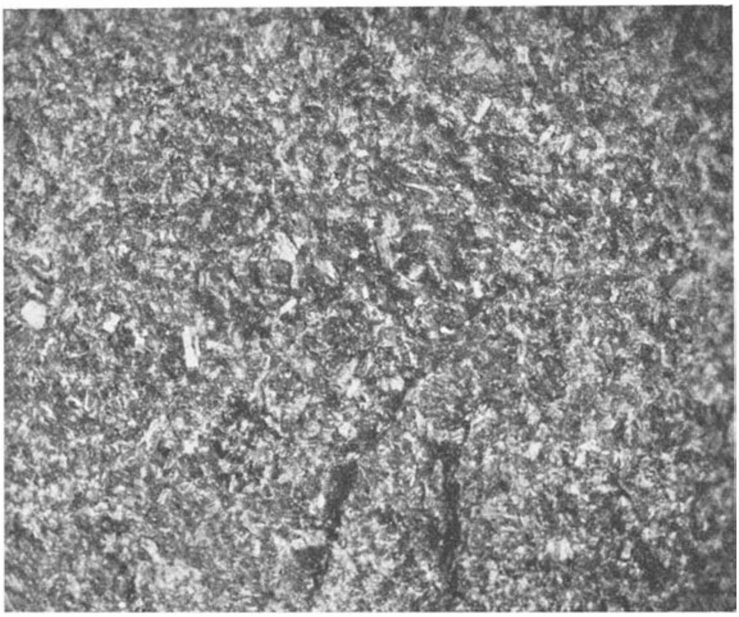

Fig. 17. Nosean-bearing aegirine-augite-syenite (1 : 1) from Hsi Kuang T'a Men (N:o III, sample 176).

trace the limits of this rock. It is a very fresh, medium grained rock of darkish grey colour and with well defined mineral contours. Glistening surfaces of felspars in laths up to 10 mm in length and squares up to 5 × 5 are very conspicuous, Small rounded grains of dark minerals are scattered throughout (fig. 17). Light brown weathering.

The rock is seen under the microscope to possess plainly porphyritic structure with phenocrysts of felspar and pyroxene in a sometimes fluxion-structured idiomorphic groundmass of rather irregularly sized laths and grains of felspar, small crystals of melanite, nosean and sodalite and ore-grains (fig. 18). The felspar phenocrysts consist of slightly sodic orthoclase with somewhat resorbed margin and numerous inclusions of sodalite and melanite crystals. The phenocrysts of pyroxene are idiomorphic and

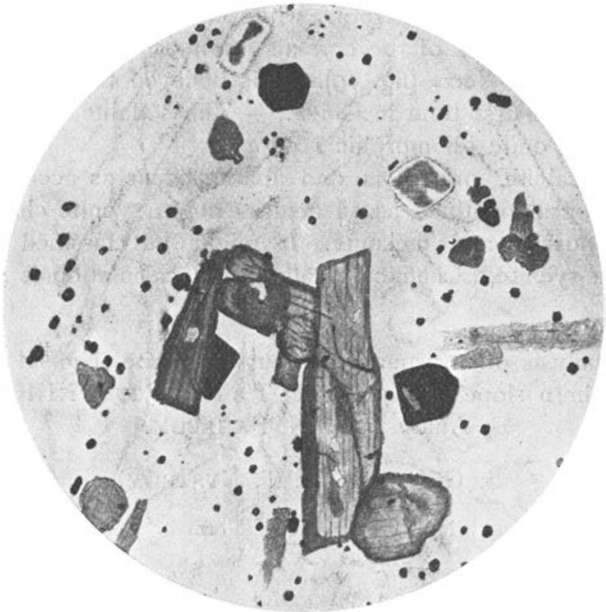

Fig. 18. Nosean-bearing aegirine-augite-syenite × 45, Nic. ∥ from Hsi Kuang T'a Men. Drawing by C. C. Sun, S. L. Tsao and K. S. Chang.

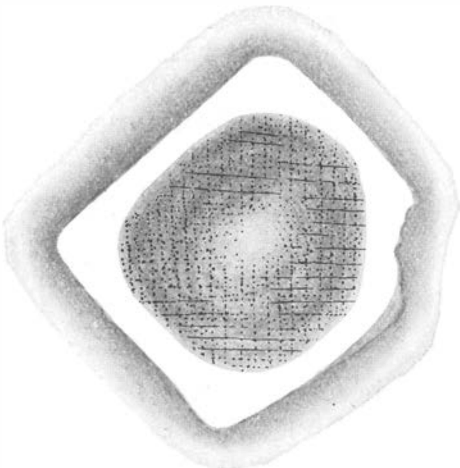

Fig. 19. Nosean crystal (× 100) from sample 176.

consist of aegirine-augite with rim of aegirine. These crystals with paler green centre and dark grass-green rim are very characteristic for this rock.

The melanite shows rhomb-dodecahedric sections of rich brown colour and is often zonary built. It contains inclusions of pyroxene and ore-grains. The minerals of the sodalite group are represented by nosean and sodalite, the former one has been identified by micro-chemical tests.

It appears as idiomorphic, isotropic, white crystals of square or hexagonal sections, the central part of the crystals often occupied by a regularly arranged black »Strich-Netz» (fig. 19). It is believed that nosean has been found here for the first time in China. — The sodalite contains no inclusions and shows quite idiomorphic sections.

Sphene, calcite, ore-grains and apatite occur as accessories. Thus the rock has been identified as an aegirine-augite-syenite characterized by presence of nosean and melanite. It might be classified as a nosean-aegirine-augite-syenite. Chemical analysis and calculation is given below:

Table 3. Analysis of nosean-aegirine-augite-syenite (N:o III, sample 176) from the northern slope of Hsi Kuang T'a Men, 500 m NNE from the top. Analyst: Dr N. SAHLBOM.

S. G. — 2,64 (E. T. NYSTRÖM).

Analysis III		Mol. Prop.	Norm		NIGGLI's System	
SiO_3	57,40 %	957	Or	38,36	qz	—40
Al_2O_3	18,57	182	Ab	36,16	si'	237
Fe_2O_3	2,27	14	An	8,34	si	197
FeO	1,33	18	Neph	3,98	al	37,5
MgO	0,74	19	Na_2SO_4	1,85	fm	13,8
CaO	3,94	70	2 NaCl	0,12	c	14,4
Na_2O	6,03	97	Σ sal	88,81	alk	34,3
K_2O	6,49	69	$CaSiO_3$	3,83	k	0,42
H_2O	0,65	36	Mg_2SiO_4	1,26	mg	0,28
TiO_2	0,60	8	Mt	2,78	ti	1,6
P_2O_5	0,29	2	Hem	0,32	p	0,4
SO_3	1,06	13	Ilm	1,22		
Cl	0,12	2	Ap	0,67		
MnO	0,11	2	Σ fem	10,08		
	99,60		H_2O	0,65		
				99,54		

Quantitative System — 1 : 5 : 2 : 3 — *Pulaskose*

OSANN's System:	s	A	C	F	a	c	f	n	k
	65,0	11,1	1,1	7,9	11	1,1	7,9	5,9	0,85

Or : Ab : An — 46,0 : 43,5 : 10,5; MgO : CaO : FeO — 36,5 : 63,5 : 0

For discussion of results see chap. V.

This is the most pronounced alkaline rock of the region. NIGGLI's high negative quartz figure (qz — 40) indicates presence of felspathoids in agreement with above description. The green-rimmed pyroxen may indicate a decrease of CaO and an enrichment of alkali towards the end of crystallisation. The chemical analysis shows much lower percentage of silica than in the other rocks. Presence of sodalite minerals is suggested by the comparatively high content of SO_3 and Cl.

Assuming that the north-western massif consists not of one but of two bodies intruded more or less simultaneously, the porphyritic and fluxion-structured rocks in the saddle between Tung and Hsi Kuang T'a Men should be interpreted as a marginal facies of the respective bodies.

As already stated, a characteristic feature of the north-western massif in contrast to the igneous bodies to the south and east of it is the

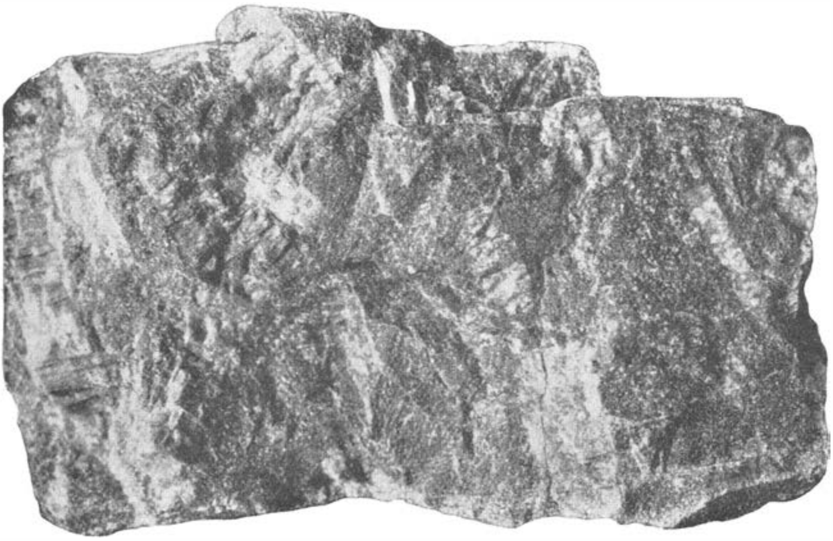

Fig. 20. Aegirine-augite-syenite porphyry (1 : 1) Dyke in NW massif.

abundant presence of intraformational dykes. These are often visible in the landscape as projecting, craggy, low ridges a few m in width and some hundred m in length. They show a coarse porphyritic, almost pegmatitic structure. A rather common type is represented by sample 134 from the northern slope of Hsi Kuang T'a Men. It is a light grey porphyritic rock with large, idiomorphic, glassy felspar phenocrysts up to 20 by 50 mm in size. The ground mass is speckled with small dark spots (fig. 20). Under the microscope the phenocrysts are seen to be of two kinds: large prisms of slightly sodic orthoclase and smaller ones of albite. A partial chemical analysis of the former (by N. SAHLBOM) shows the following result:

K_2O	11,33 %
Na_2O	2 77
CaO	0,46

The groundmass is fluxion-structured and composed of lath- or needle-shaped crystals of orthoclase and albite, also the same green-rimmed pyroxene as in sample 176 (cf. above). This groundmass is densely interspersed by idiomorphic grains of sodalite, nosean, melanite, ore-grains, sphene and apatite. This rock was evidently produced by the same magma from which the above described specimen, sample 176, originated, and it may be called a nosean-aegirine-augite-syenite porphyry.

To the same magmatic period belong also probably the sills intruded in the sediments near Ch'ang Kan Kou (see above, p. 91). A specimen collected from the sill one km NNE of the village is a dark maroon-coloured porphyry with fluidally arranged, pink, lath-shaped felspar-phenocrysts up to 2 by 9 mm in size in a dense groundmass. Another sill near by and less decomposed is of blue-grey colour with white felspar-phenocrysts and contains apart from the usual main constituents (orthoclase and albite) also brown melanite, thus indicating relationship to the main massif.

Laccolithic remnants on top of Hu Yeh Shan. As already stated on p. 78 the strong metamorphism observed on top of Hu Yeh Shan cannot be explained otherwise than by assuming the presence in the past of at least one ancient, superimposed laccolith, which is now largely eroded away. The small igneous body of Tung Hsien and possibly also that of Wang Mu (cf. map Pl. II) are remains of this laccolith. The former one is an isolated flat-lying, wedge-shaped body of igneous rock which underlies the actual top of the peak. The 50 m high outcrop towards the east may be followed for about 1000 m towards south-west and west.

It may extend north-westward to a place just north of the little »hump», pt 2186, below Tung Hsien, connection being uncertain on account of thick covering of débris.

It is assumed that this igneous wedge below Tung Hsien which thins out towards west represents part of the edge of a hypothetical laccolithic body which has existed in the region towards east and north-east of the mapped area.

The rock composition of this wedge is not uniform. The escarpment towards north-east is a grey and coarse porphyritic åkerite whereas a sample taken near pt 2186 towards NW (sample I: 3) is macroscopically and microscopically so strikingly similar to the intraformational dykes of the north-western massif that renewed description is unnecessary. Connection being as stated above uncertain, this rock may not be part of the wedge, but an independent dyke. The south-western part of the half-moon shaped outcrop of the wedge is composed of a nearly white rock only found here (sample 203). It contains phenocrysts of perthitic orthoclase, basic andesine and diopside in comparatively large, polysomatic crystals. Sphene, apatite and a few ore-grains are accessories. The chief characteristic of this rock is the presence of much melanite, which is light brown in colour and allotriomorphic. It is perfectly isotropic and has inclusions of felspar. The melanite has crystallised even later than the alkali felspar (fig. 21, where the black portions are melanite). This rock may be called melanite-augite-syenite-porphyry.

The igneous remnant of Wang Mu forms an outcrop of irregular shape (se map Pl. II). It is partly covered by sediments, partly lying free on a slightly sloping surface. It is possible that towards south-west connection exists with the underlying large laccolith and the remnant shows under the microscope similarity in composition to this body. It is an åkeritic rock of grey colour and medium, rather even grain.

Fig. 21. Melanite-augite-syenite porphyry (×100, Nic. +) from Tung Hsien. The central crystal is sphene.

Summarising the above we may say that the young intrusives of central Chiao Ch'eng district all belong to the syenitic family with certain variations of type. It has been possible to define three main categories of rocks: the oldest intrusion is the åkeritic magma of the large southern laccolith and its accompanying sills; probably younger than this is the massif of Ch'i Huo Ch'i Tung which is a chonolithic intrusion of nordmarkite porphyry. This may be interpreted as an acid and alkaline product of differentiation of the above mentioned åkeritic magma. Slightly later than this intrusion is the aegirine-augite syenite of the north-western stock and its associated dykes and sills. This stock cuts across not only the sediments but also the main Sui Kung Kou faultline. To this eruptive stage may belong also the laccolithic remnants on Hu Yeh Shan. Lastly, the step faults along the north-western margin of the mapped area are due to post-volcanic dislocations.

Concerning the geological period during which these rocks have been intruded, no exact conclusion has been arrived at. The youngest sediments which have been penetrated by the magma belong to the Permian Upper Shihhotse series (cf. p. 72). This gives us the lower time limit of the intrusion. Unfortunately no younger strata than these are locally preserved, and therefore it is not possible to state an upper time limit, except by analogy and circumstantial evidence. This aspect will be more fully treated in chap. VI, which deals with the correlation of the Shansi alkaline rocks.

II. The Lung Wang Miao Intrusive and Surroundings.

Field-work by C. C. SUN, S. L. TSAO and K. S. CHANG.
Compilation and petrography by E. T. NYSTRÖM.

Location and Topography.

In the early part of 1925, on the occasion of a visit to south Shansi by myself and the three assistants of the Nyström Institute, some boulders of igneous rocks were discovered in the river-bed Po P'i Ho which drains into the P'ing Yang Basin from south-east. The assistants were given the task to try to locate the origin of these boulders and in this manner the Lung Wang Miao intrusive was discovered. The preliminary survey, which was rendered difficult through the thick loess-covering, lasted about four weeks, and at the end of the year Mr C. C. SUN again proceeded there to complete the map and description.

The visible outcrop of the Lung Wang Miao intrusive occupies a roughly elliptical area 8 km in width and 12 km in length, the centre of which is situated at lat. 35° 50′ N. and long. 111° 40′ E., or about 30 km SSE of P'ing Yang Fu in south Shansi (see map, fig. 1). It marks the meeting point of the districts Lin Fen (new name for P'ing Yang), Hsiang Ling, Chü Wo, Yi Ch'eng and Fou Shan. As seen on the map it lies on the direct continuation of the lines of volcanics marked by Liang Chia P'o — Tung T'ai Shan and is situated 10 km south of the latter. In the central part of the igneous body lies the village Lung Wang Miao, hence the name given to this intrusive.

One of the most striking features of southern Shansi is the so-called Fen Ho Graben, already described by VON RICHTHOFEN and figuring conspicuously on his map (cf. 22). It is named after the river Fen Ho and runs in almost straight direction NNE-SSW between the basins of Taiyuanfu and P'ing Yang Fu with nearly parallel sides and a width of about 50 km. Its nature of graben is sometimes more geologically than topographically in evidence, as part of it is occupied by a transverse anticlinal fold (between Ling Shih and Ho Chow) and, moreover, a vast mass of loess sometimes obscures its real character.

But a geologic map will show very typical graben features. Its delimitations are: to the east the high and straight Ho Shan mountain range, being the up-throw of a fault of 2500—3000 m magnitude[1] and towards west the equally conspicuous but lower Ngo Shan also a fault-escarpment, which appears as a mountain range from the bottom of the graben.

Towards the south the Fen Ho valley widens so as to form the basin of P'ing Yang Fu. The trendlines seem here to suffer a rather abrupt change of direction (cf. above p. 67) and it seems scarcely accidental that intrusives should be found here as a result of the doubtless profound dislocations at the intersection of the two trendline directions.

The P'ing Yang basin extends in a bay towards east, so that the Ho Shan faultline (v. RICHTHOFEN, 22, Vol. II, p. 405) cuts through the basin. Honour must be given to this keen explorer as erosion has here largely removed the fault features, and moreover an enormous covering of loess makes observations very difficult. v. RICHTHOFEN paid his visit to the P'ing Yang region in May 1870.

The intrusives to be described in this and the following chapter are all near this more or less hidden fault-line. The plainest testimony of dislocation exists in the shape of a short intrabasinal range of rather low altitude seen from P'ing Yang Fu towards ESE and SE. It runs NNE-SSW for about 20 km and attains a max. altitude of about 600 m above the plain. It is called in the north Shih Tsun Shan and in the south Tung T'ai Shan. It is composed of Permian or younger sandstones and shales. Apart from this small range which lies in the eastern half of the P'ing Yang depression the aspect from that city is that of a real basin.

This basin is the fourth from the north of those six depressions which lie very characteristically *en échelon* more or less along the central longitudinal axis of Shansi province. BAILEY WILLIS (28, Vol. II, p. 109) calls this zone one of the major structure lines of the Asiatic continent, agreeing in general trend with the directions of folding of Pre-Cambrian as well as of Permo-Mesozoic deformation. WILLIS adds that in the recent extraordinary diastrophism it has again been manifest in marked differences of elevation.

The intrusives of the P'ing Yang basin known to date are:

1) The large Lung Wang Miao laccolith (various rocks from åkerite to nordmarkite and quartz porphyry, also banatite porphyry) with centre

[1] Mr C. C. WANG of the Geological Survey of China who has made a study of the tectonics in Shansi is inclined to consider the Ho Shan to be an anticline. But the steepness of its western limb would be likely to entail fissuring (faulting) as well. (Cf. WANG 27).

about 32 km SSE of P'ing Yang city. Some small satellites have been found belonging to this intrusive.

2) The two necks of åkerite at Tung T'ai Shan 22 km SE of P'ing Yang.

3) The Shih Tsun Shan dyke of åkerite porphyry 20 km SE of the town.

4) The Liang Chia P'o intrusive, a chonolith of analcite-syenite porphyry 25 km ESE of P'ing Yang.

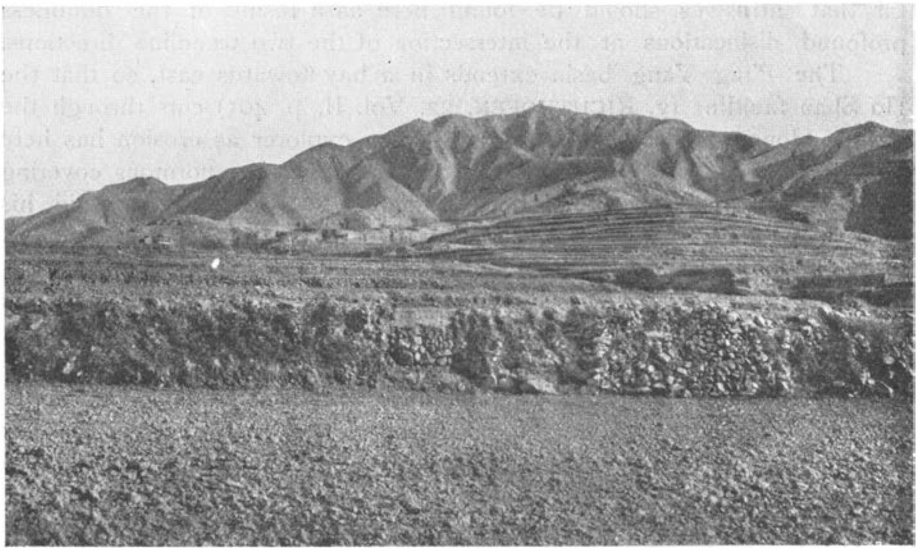

Fig. 22. T'a Shan from NW. The western part of Lung Wang Miao intrusive.

With a view of studying the surroundings of these igneous bodies it is advisable to proceed eastwards from P'ing Yang city to the rim of the basin and then make a circular tour towards south, west and north. Before reaching the mountainous rim of the basin we enter the low Fou Shan plateau land, which stretches from Ho Shan in the north for about 90 km to the Lung Wang Miao massif in the south and with a width of about 30 km. The features of this plateau land which shows a somewhat rugged surface are of the usual trend NNE-SSW. In the north the plateau and its covering of loess has been cut by numerous long valleys and deep gulleys leaving ridges from about 750 to 900 m above sealevel. At the southern margin of the plateau lies the rather impressive T'a Shan range of E-W trend (fig. 22) the larger part of which is occupied by the Lung Wang Miao intrusive. The T'a Shan peak being the highest eminence of this range reaches 1579 m. The igneous rocks here vary greatly in their composition and in their ability to withstand erosion, consequently the area is dissected in numerous rocky peaks.

This eruptive appendix which protrudes towards west is flanked by two depressions, one of which — the P'ing Yang basin — has already been described. The other, southern one is the Yi Ch'eng basin which, with the exception of some hummocks, forms an almost flat surface with an altitude of about 840 m. Westwards it joins the valley of the Fen Ho, towards south it extends to the slope of Feng Huang Shan and its length N-S is 25 km. In the central part of this basin stands a small lonely hill, Mien Shan, altitude 995 m, which is composed of Ordovician limestone and harbours a small intrusive (see p. 115 and section Pl. III).

The rivers of the district are not important. Numerous riverbeds — dry during most part of the year — run down from the main intrusive body, then cut through the loess and ultimately drain into the Fen Ho directly or into the Yi Ch'eng basin. The rocks belonging to the intrusive are comparatively very resistant, consequently erosion is restricted in the upper valleys to downward cutting, making narrow gulleys, wheres the lower parts of the river beds cut in sediments and loess, gradually become wide.

Local sequence of stratification.

In section A, Pl. III, a tentative profile is given of the sedimentary sequence in the district. Exposures round Lung Wang Miao are rather scarce on account of the thick loess-covering and in some places the section may therefor prove to be incomplete. We find in ascending order:

I. Unaltered or Crystalline limestone (marble) probably Ordovician

II. The Ch'ing Feng Ting series
   1. Coalbearing Carboniferous (see detailed section B, Pl. III)
   2. Light coloured greyish and greenish sediments

III. The Shih Tsun Shan series
   1. Chocolate-coloured shales and sandy sediments
   2. Very compact green sandstone of great thickness.

Fossils not having been found in series I the exact position of it is not settled, but it strongly reminds one of the Ordovician. The series II and III are similar to the Palaeozoic sediments of central Shansi and probably belong to the Late Lower Carboniferous and Permo-Carboniferous.

The uppermost part of the series, viz. the compact green sandstone, III: 2, is not represented in the standard section of central Shansi, but its lithological character, according to NORIN, reminds one of the sandstone series of the Lin Hsien plateau in westernmost Shansi. This formation, the age of which is not known, is superimposed on the red Lower Permian series.

The largest exposure of the Ordovician limestone occurs in the western part of the T'a Shan range (cf. section B, Pl. III), the slope here consisting almost entirely of this limestone, dipping 20° westward. The north-west slope has dips towards NW and disappears under the loess. Towards SW the limestone forms a series of precipitous hills reaching 1500 m, the dips being here towards WSW. Here the limestone is mostly thin-bedded, black or dark grey, except in contact with the igneous body when it has been transformed to white marble. The limestone is often covered by the red »Hipparion» clay which contains lime concretions (cf. p. 72). Along the northern slope of T'a Shan the limestone is also laid bare in a long and almost continous belt which dips towards NNW at various angles of 25° to 35°. In some places it occurs as inliers (cf. p. 86) inside the igneous body. Its normal thickness is no doubt considerable, but its base has nowhere been seen. Much of it has been changed to marble, either grey, whitish grey or immaculately white. On account of numerous joints, large blocks of marble are difficult to obtain, hence it is not used as building stone or for decorative purposes. The considerable thickness, the lithological nature and the surface attacked by ancient erosion, all pronounce it to be the common North China Ordovician limestone.

The Permo-Carboniferous **Ch'ing Feng Ting series** rests as in central Shansi disconformably on the Ordovician. The black and grey claystones so common in central Shansi are scarce and coal-seems nearly absent. The total thickness measured near Po Chia Yü is rather less than 200 m. North of Lung Wang Miao the most important exposure of this formation is that which forms the Ch'ing Feng Ting ridge in which the strata have various dips of 20° to 38° in a NNW direction (see section A, Pl. III). Here the sandstone, the uppermost part of the series, plays an important role, being about 160 m thick. It is greenish grey but weathers a dark brown. It is conformable below with the other members and above with the Permian formation which shall be called the Shih Tsun Shan series (see below). It is sometimes quartzitic, probably due to igneous influence.

In a tributary valley to Po Chia Yü Kou a coal-seam is found in the horizon of black argillaceous slate. Towards east this same very thin, shaley coal-seam crops out in the Yen Wo Ch'ang Kou but from information of natives a coal-seam one foot in thickness is said to exist north-east of T'a Shan. There the coal-measures dip towards NW and then gently bend down into the valley of the Fen Ho. It is not impossible that this is the one observed by v. RICHTHOFEN many years ago. In the black shale we have found plant-remains which are similar to *Alethopteris Armasi* and *A. plebeia,* both well-known Permo-Carboniferous plants.

South-west of T'a Shan in the neighbourhood of Hsieh Chia Chuang village the Permo-Carboniferous is well exposed forming low rounded hills.

The contact with the Ordovican is also visible. It is intruded by sills originating from the main intrusive (see section B, Pl. III).

The sequence is from below (from the top of the Ordovician):

1.	Argillaceous, blue-grey shale	2 m
2.	Grey quartzose finegrained sandstone	0,3 m
3.	Coal Seam	0,3—1,0 m
4.	Dark, coaly marl	1,5 m
5.	Igneous rock ressembling T'a Shan mass	35,0 m
6.	Very fine, blue-black limestone	3 m
7.	Medium-grained, quartzose, grey sandstone	1 m
8.	Blue-black limestone with black flints	4 m
9.	Red or grey calcareous shale	0,3 m
10.	Dark grey coarse-grained quartzose sandstone	9 m
11.	Grey fine argillaceous slaty shale	5 m
12.	Dark green fine-grained sandstone	1 m
13.	Dark compact argillaceous plant-bearing shaly slate	9 m
14.	Intrusive sheet similar to No. 5 above	50 m
15.	Very fine, argillaceous dark slaty shale	25 m
16.	Sandy dark green shales	60 m
17.	Greenish yellow or grey sandy shale, interbedded with yellow fine-grained sandstone	70 m
	Thickness of sediments about	200 m

The existence of two marine members in the lower part of this series is notable and this fact should be compared with corresponding conditions in central Shansi (cf. p. 65). The existence of only one coal-seam is further proved by a visit to the three coal-mines 1 km southeast of She Chia Chuang where the thickness of the seam is also one m. The coal is mostly pyritic. Nothing can as yet be said about the western-most part of the Carboniferous as this has not been subject to our investigation. Southeast of the intrusive body a small area of Carboniferous is also exposed forming the Chu T'ou Shan.

The Shih Tsun Shan Series is younger than the Ch'ing Feng Ting series and consists of green compact sandstones and very sandy purple shales. The detailed profile (section A, Pl. III) may be studied in this connection. The purple shale lies between the two sandstone series and is seen to crop out in a small valley south of Shih Tsun Shan, there underlying the bed of green sandstone. It is again observed along the southern tributary to Po P'i Ho, 1 1/2 km north of Ch'ing Feng Ting, where it lies conformably upon the greenish grey sandstone of the Ch'ing Feng Ting series. This purple shale is quite identical not only in colour but also in lithological character with Later Permian shales in other localities in Shansi. The roof of this formation is a green compact sandstone which, with strongly eroded surface, yet shows a remaining thickness of 240 m. It is exposed only in two localities, viz. Tung T'ai Shan and Shih Tsun Shan (cf. chap. III). At the latter place it is seen to lie directly upon the purple shale. Its composition is of fine white quartz grains in a bright green cement.

Tectonics.

Broadly speaking, the structure of the surroundings of the Lung Wang Miao intrusive are characterised by extensive or local synclinal and anticlinal foldings, more or less important faultings and abundant igneous intrusions. During the reconnaissance on the low Fou Shan plateau two anticlinal foldings were found which constitute the essential factors of topography and structure. An anticline of greater magnitude is the T'a Shan range, in the axial part of which strong erosion has laid bare the wide outcrops of the Lung Wang Miao intrusive mass. About parallel to this and 20 km northwards there is an other anticline—the Man T'ien Ling—which stretches from the western margin of Fou Shan plateau several tens of km westwards. It is composed entirely of alternate beds of purple shales and greenish grey sandstones. Beside these major foldings there are probably numerous local ones in the northern part of Fou Shan plateau.

The strata of this region have been disturbed not only by the folding just mentioned but also by the NNE—SSW faulting of Ho Shan (cf. p. 101). Thus we notice here the dual influence of two systems of trendlines.

The folding, probably of Mid-Mesozic age, was followed by the faulting representing the Caenozoic Fen Ho diastrophism and the twofold dislocations resulted in the intrusive action producing the igneous bodies here described. In the case of the main Lung Wang Miao massif the intrusion took place (note similar conditions in central Chiao Ch'eng, p. 73) about 100 m below the ancient Ordovician surface.

We found in many localities that this limestone appears to have been subjected to stronger metamorphic action than the other sediments. In the Po Chia Yü valley the contact-metamorphic zone in limestone is more then one km broad and the metamorphism extends also greatly upwards whereas in a valley south of Liu Chia Chuang the greenish grey sandstone apppears at the contact not to be subjected to strong transformation. This is further proved by the fact that in Shih Kou valley we found angular green sandstone-fragments embedded in the igneous rock (specific gravity of these rocks being 2,70 and 2,59 respectively). This sandstone evidently originated from the typical member of Shih Tsun Shan series above described and had still its original texture and colour preserved.

The Alkaline Intrusives.

Though marginal exposures are rather scarce we have — broadly speaking—been led to consider the igneous mass as a laccolithic injection in the Ordovician limestone. At first sight the body looks like a stock, because its contact surfaces clearly cross-cut the limestone and younger sediments in many places. Yet, on the whole its relations with the invaded limestone which has a rather strong and universal outward dip, being seemingly lifted by the underlying magma, seem to prove its laccolithic nature. The magma after raising its cover seems finally to have broken up part of the roof into blocks. In agreement with this supposition an igneous mass is observed 2 km west of Hsiu Chia Chuang intruded as a sill which crops out on both sides of the valley, below the comparatively thick (200 m) cover of limestone.

Fig. 23. Central part of Lung Wang Miao intrusive seen from the east. Partly covered with loess terraced by cultivation.

The principal part of the laccolithic body (fig. 23) extends on all sides below the cover of the limestone, as indicated by the extensive contact metamorphism and the existence beyond the main igneous area of numerous satellites (for instance at Mien Shan towards the south) which show evident relationship with the principal body not only in emplacement, but also in petrographic composition.

The igneous rocks of Lung Wang Miao are generally deeply weathered especially in the southwestern part. They are mostly whitish grey or pinkish white on exposure. They have not been subject to far-reaching secondary transformations such as those caused by hydrothermal action or tectonic forces. The mass may be very fine-grained to coarse-grained, but almost throughout the felspars occur abundantly as phenocrysts and the bisilicates as black prisms thus giving the rocks a porphyritic appearance. Rocks of the alkali-syenitic family form the northern part of the main body. Through change in mineral composition, a rich variety of derivatives have been produced. Thus the typical northern alkali-syenite (åkerite) changes from N to S into alkali-granite-aplite and quartz-porphyry which is very rich in quartz but almost lacking in dark minerals. The westernmost (T'a Shan) rock form a plagioclase-rich differentiate of the åkerite and may be called banatite-porphyry. In the eastern part of the massif the rock is rather similar to the åkerite but of more acid composition and may be called a nordmarkite.

Fig. 24. Åkerite (1 : 1) (sample 414) from N part of Lung Wang Miao intrusive.

The åkerite (sample 414) is the principal rock of the massif and occupies its central and northern part extending southwards to pt 1320. An isolated small outcrop occurs near Ch'ing Feng Ting and by this we know it to extend northwards under the sedimentary cover. The Tung T'ai Shan necks which lie 10 km to the north and which will be described in the following chapter, are also closely related to the Lung Wang Miao åkerite. The latter forms a region of low rounded hills. Near pt 1250 it is fissured by a series of cleavage joints forming slabs which are quarried for building purposes. Towards south, east and west it borders upon other igneous rocks, but towards north its contact with the sedimentaries is sometimes well exposed: these are towards NE Carboniferous sandstone but in the Po Chia Yü valley the åkerite adjoins with almost vertical contact the Ordovician limestone which has a northwestern dip. The limestone attains locally 1100 m altitude and is strongly marmorized. Further away the marine limestones of the Carboniferous have also been subject to metamorphism. Within the north-east portion of the åkerite a few dykes of nordmarkite (quartz-syenite) are scattered, the sharp contacts indicating that they are considerably younger than the main rock-body.

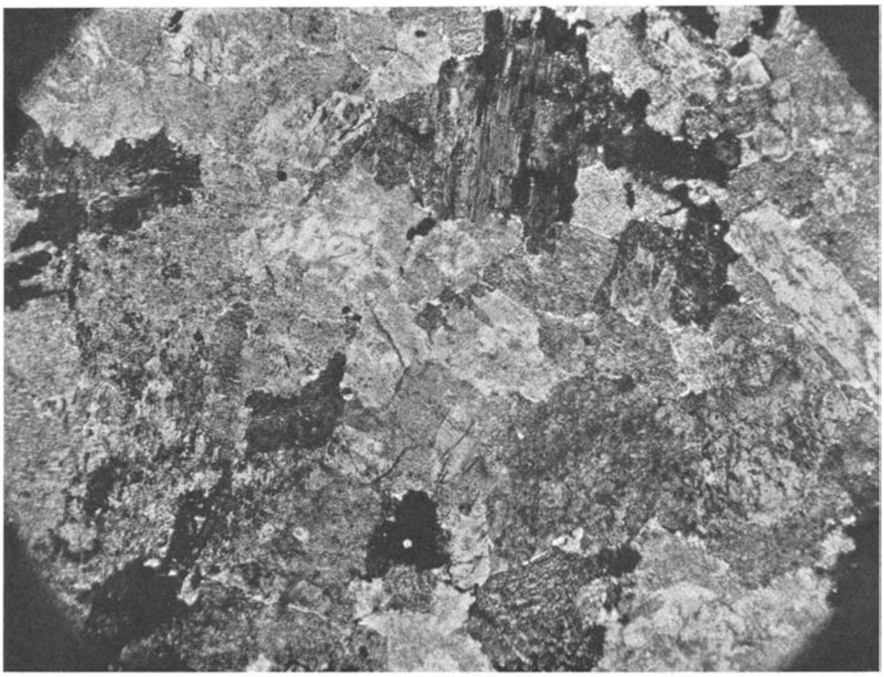

Fig. 25. Åkerite (× 50, Nic. +) from Lung Wang Miao.

The åkerite (fig. 24) is a medium-grained rock which towards the margin becomes sometimes very coarse-grained. It is light pearl-grey with greenish spots. Fresh specimens show typically the pearl-grey felspar in closely packed reflecting crystals up to 3 by 12 mm in size. The spots represent highly decomposed bisilicates.

Under the microscope (fig. 25) the association of minerals is seen to be: alkali-felspar, a little less of plagioclase, pyroxene and accessory sphene and ore-grains. The alkali-felspar is orthoclase, beautifully perthitic, containing rounded or idiomorphic inclusions of plagioclase crystals. The plagioclase is oligoclase with extinction of $+ 2^\circ$ in the symmetrical zone. The pyroxene is an augite, highly decomposed with c : Z about $= 40^\circ$. A fair amount of sphene exists which is slightly pleochroic. Quartz is absent. The rock may be classified as an augite-bearing, quartz-free åkerite.

Within this principal igneous body there exist at some places more femic varieties appearing as more or less well defined »Schlieren» and irregular patches. Another more fine-grained variety of the principal rock shows exceeding similarity to the Tung T'ai Shan main intrusive (cf. chap. III).

From the åkerite have originated a series of more acid derivatives partly predominating in orthoclase, forming nordmarkite, partly with plagioclase preponderant and then forming banatite porphyry.

The nordmarkite (sample 425) occupies the eastern part of the area and forms a series of hills partly covered by red »Hipparion» clay. Several

Fig. 26. Nordmarkite (× 15,5, Nic. +) from eastern part of Lung Wang Miao intrusive.

small patches are found within the åkerite area. It is a medium-grained, whitish grey rock in hand-specimen rather like the Tung T'ai Shan rock (cf. fig. 33) but perhaps with less of dark minerals. It is even-grained, with dark minerals very subordinate. It shows a characteristic light brown weathering.

Under the microscope (fig. 26) the mineral composition is seen to be: perthitic orthoclase, oligoclase, quartz and amphibole with pleochroism in very light yellow and blue green. Another sample near bye contains diopside with a little magnetite and biotite as well.

Along the north-western boundary the nordmarkite is bordered by the åkerite with a not very distinct contact and it seems that the latter was not quite solidified when the nordmarkite was intruded. West of

Ch'u Chuang the contact line is more distinct and the åkerite (here more porphyritic) adjoins very coarse-grained nordmarkite, the marginal rocks are fluxion-structured.

The banatite porphyry occupies the westernmost part of the Lung Wang Miao intrusive. It forms the highest eminence of the area, T'a Shan (fig. 22, p. 102), 1579 m. Four km SW of this peak two isolated small sills were found in the Carboniferous sediment (see section B, Pl. III). A small mass was also found within the åkeritic area. Inliers of limestone are often seen, but dykes and veins are rare. The rock is sometimes traversed by several sets of »shrinkage joints» producing semblance to columnar partings. This rock is comparatively resistant to weathering

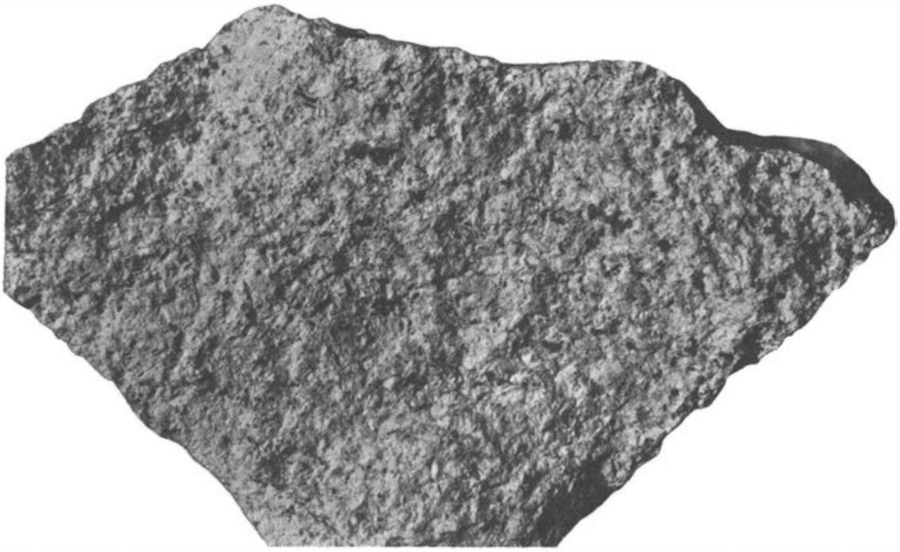

Fig. 27. Banatite porphyry (1 : 1) from western part of Lung Wang Miao intrusive.

and therefor mostly fresh, only in some places has its felspar component been reduced to a white powdery substance.

Towards west and north the vertical contact between banatite-porphyry and Ordovician limestone has been well laid bare. The contact line attains 930—1560 m altitude. At a point about 3 km northeast of T'a-Shan peak many contact minerals were found such as aggregate of garnet crystals impregnated with iron-ore. This was within or very close to the igneous mass. Further away and included in the marble occurs quite abundantly a dark red iron-ore (hematite), the quantity of which is not easily estimated on account of loess-covering, but the outcrops of which are sometimes several m wide. Towards west the contact zone is 100—300 m wide in which the Ordovician is metamorphosed either to white fine-grained marble or to a blue-grey porous substance. Near the contact the banatite porphyry becomes still more porphyritic. Towards east it merges gradually into the åkerite.

In hand specimens (fig. 27) the banatite porphyry, sample 427, is a light grey to pinkish white, plainly porphyritic rock very similar in appearance to the rock of Ch'i Huo Ch'i Tung of central Chiao Ch'eng (cf. p. 86). Small black prisms of bisilicates up to $^1/_2$ by 3 mm in size are seen irregularly scattered throughout. Phenocrysts and groundmass are about equal in quantity (sem-patic structure).

Under the microscope (fig. 28) the rock is seen to consist of phenocrysts of plagioclase and, subordinately, of potash felspar in a microgranitic groundmass of potash-felspar, quartz, amphibole and accessories.

Fig. 28. Banatite porphyry (× 13, Nic. +) from Lung Wang Miao intrusive.

The plagioclase is an oligoclase ($Ab_{71}An_{29}$). It shows splendid zonary structure. The amphibole is common hornblende with $c:Z = 18°$ and pleochroism on basis yellow and deep olive green, and on sections parallel c blue green.

This is a rock of quartz-dioritic composition and may be classified as *banatite porphyry*.

Proceeding from the centre of the åkeritic area southwards and passing village Lung Wang Miao quartz begins to enter as constituent of the intrusive. At a place 3 $^1/_2$ km south of the village the rock has acquired a thoroughly aplitic character and is very fine- and even-grained and of yellowish pink colour, femic minerals are very scarce. Sample 417 of this rock shows the following appearance under the microscope (fig. 29).

The structure is an equigranular mosaic with grains of average 0,25 mm consisting of quartz (about 40 %), perthitic potash felspar (55 %) and albitic plagioclase (5 %). Magnetite exists and is perhaps partly a decomposition product of bisilicates. The rock is classified as an **alkali-granite aplite.**

It may be assumed that this rock has been intruded along the southern rim of the åkeritic body before this magma was completely solidified, hence the absence of definite contact.

Along the southern rim of the Lung Wang Miao intrusive we find a flat curved lenticular body of **quartz-porphyry**, intruded between the

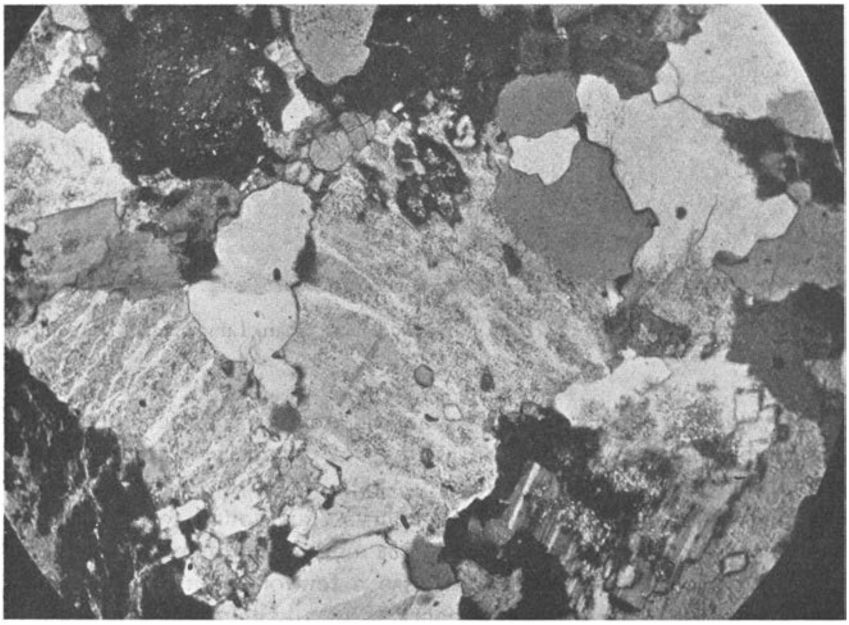

Fig. 29. Alkali-granite aplite (× 69, Nic. +) from Lung Wang Miao intrusive.

Ordovician limestone and the aplite just desribed. The contact between the two being indistinct we must assume that neither rock was completely solidified at the time of intrusion.

Its southern contact with the sedimentaries is not seen, except towards SE where it is exposed in several deeply eroded valleys. At the contact 1 km north of Ku Shu Tsun the rock shows gneissic appearance. Near Szu Chia Wan village in the contact between the acid rock and limestone there is a vein of malachite and according to information from the natives a company worked here for a long time extracting copper, but afterwards ceased operations.

The quartz-porphyry, sample 416, from Shih Ku Niang Shan (fig. 30) shows a light pink dense groundmass, richly crowded with large and

Fig. 30. Quartz-porphyry (1 : 1) from Shih Ku Niang Shan. Lung Wang Miao intrusive (No. VI, 416).

small crystals of felspar and bi-pyramidal quartz of perfect development up to 12 by 20 mm in size. Both kinds of phenocrysts are found weathered out and lying on the ground (fig. 31).

Under the microscope the phenocrysts are found to be quartz and potash felspar in a finegrained (0,02—0,08 mm) groundmass of quartz, alkali felspar and subordinate plagioclase, also a few ore-grains. No bisilicates are seen in this slice. The phenocrysts of alkali felspar are beautifully perthitic and show somewhat resorbed margin. They frequently include cores of solid plagioclase in crystallographically parallel position. The

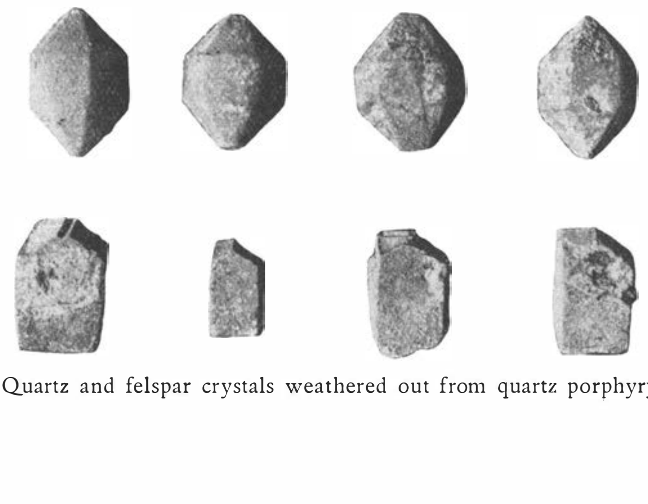

Fig. 31. Quartz and felspar crystals weathered out from quartz porphyry (fig. 30).

perthitic strings show often albite twinning. The large quartz crystals are very strongly resorbed and include numerous small albite crystals often arranged in strings; extinction is not undulose. The felspar of the groundmass is mainly potash felspar, plagioclase enters to an amount of about 5 % in the groundmass. It is albite or oligoclase-albite and is fairly idiomorphic against the other constituents.

A chemical analysis and calculation of this rock (No. VI, sample 416) is given below:

Table 4. Analysis of quartz-porphyry from Shih Ku Niang Shan, S Shansi, by N. SAHLBOM.

S. G. — 2,54 (E. T. NYSTRÖM).

Analysis VI		Mol. Prop.	Norm		NIGGLI'S System	
SiO_2	73,48 %	1225	Qu	22,74 %	qz	120
Al_2O_3	14,20	139	Or	28,36	si'	285
Fe_2O_3	0,85	5	Ab	46,11	si	405
FeO	0,14	2	Σ sal	97,21	al	46
MgO	0,14	4	Acmite	0,92	fm	6
CaO	0,18	3	$MgSiO_3$	0,40	c	1
Na_2O	5,55	90	Ilm	0,15	alk	47
K_2O	4,79	51	Mt	0,23	k	0,36
H_2O	0,33	18	Hem	0,32	mg	0,25
TiO_2	0,05	1	Ap	0,34	ti	0,33
P_2O_5	0,10	1	Σ fem	2,36	p	0,33
MnO	0,01	0	H_2O	0,33		
	99,82			99,90		

Quantitative System — I. 4 : 1 : 4 — *Kallerudose*

OSANN'S System:	s	A	C	F	a	c	f	n	k
	80,41	9,35	0	1,14	17,8	0	2,2	6,38	1,41

Or : Ab : An — 38,08 : 61,92 : 0; MgO : CaO : FeO — 100 : 0 : 0

High tenure of free quartz and alkalis and exceedingly low percentage of calcium and bisilicates is the characteristic of this rock. For further discussion see chap. V.

The Mien Shan Intrusive. The small intrusive in the hill Mien Shan, which, as mentioned above, stands isolated on the Yi Ch'eng plain south of Lung Wang Miao massif, may be considered as a satellite of the main body. The hill is situated 5 km south of Ku Shu Tsun which lies at the south rim of the mapped area (see Pl. III). The Mien Shan hill consists of Ordovician limestone and the intrusive crops out as a conformable sill-like body in the northern part of the hill. In hand-specimens the rock ressembles the T'a Shan banatite porphyry.

All the rocks of the Lung Wang Miao intrusive: the åkerite, the banatite porphyry, the nordmarkite, the granite-aplite and the quartz-porphyry are so intimately connected with each other in the field by transition forms (which have not been described here) that it is necessary to assume that they have all originated from the same magma-reservoir the content of which has probably been of åkeritic composition. All the rocks belong to the same eruptive epoch. They have been injected in the order in which they are described above and with such short intervals of time that one had not solidified before the next one was intruded. The age relation between the nordmarkite and the banatite porphyry is not settled because the two are not in contact.

Regarding the emplacement characterising the Lung Wang Miao intrusive body it belongs to a type quite different to the central Shansi eruptives. As mentioned in the introduction to this paper south Shansi belongs to the foreland of Tsing Ling Shan and as such shows the influences of the lateral forces which have been active in forming this range. Thus the Lung Wang Miao åkerite has been injected in an anticlinal fold. In contrast to this the structure of central Shansi is governed by vertical tectonic movements which have occurred along faultlines, with the formation of which igneous action has often been associated.

III. The Tung T'ai Shan, the Shih Tsun Shan and the Liang Chia P'o Intrusives.

The existence of igneous bodies north of the Lung Wang Miao area has already been briefly indicated. 10 km north of T'a Shan there are two necks of åkerite which show close relation to the presumed parent rock of the Lung Wang Miao intrusive.

These necks are situated at the southern end of the intrabasinal range mentioned above (p. 101). The somewhat unusual aspect of this terminal part was the cause why an excursion was undertaken in this direction from P'ing Yang Fu and the excursion resulted in the discovery of the Tung T'ai Shan and indirectly the Lung Wang Miao intrusives. The terminal southern projection of the range has an appendant small hill, the Tung T'ai Shan, stretching E—W, which is almost covered with temples built in honour of Liu Ho, who was a minister of state during the Han dynasty (about the beginning of the Christian era). It is about 250 m above the P'ing Yang plain and 750 m above sea-level. The igneous rock in this hill is confined to a short dyke in its eastern part, which dyke is an outlier of the main stock which occupies part of the southern slope of the intrabasinal range and forms on it a projecting appendix called Pan Shih Shan, »Half Stone Hill». The reason for this name is that one slope is covered with loess and the other one is bare.

The appendix does not project in the same direction as the main range but in a true E—W direction. On the higher parts of its western slope black crags show from far away. It is a neck-like intrusion rising about 90 m above its surroundings and is egg-shaped in section, of 400 m length and 200 m width with max. altitude 825 m. The other intrusive lies about 300 m towards NE, it is nearly elliptic in section with axes 100 and 120 m approximately. Max. altidute 785 m (see sketch map, fig. 32).

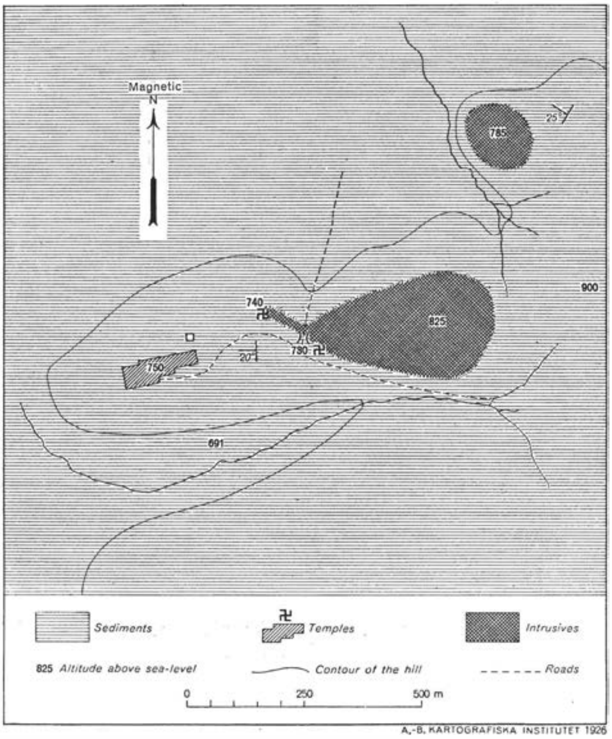

Fig. 32. The Tung T'ai Shan intrusives.

There are low loess hills to the south of the larger intrusive, but no visible outcrops until about 10 km away, where a very high escarpment is seen crowned by a pagoda. This is the T'a Shan (Pagoda Mountain) of the Lung Wang Miao area (see p. 102).

The existence of the intrusive bodies of Tung T'ai Shan has had a certain influence on local topography inasmuch that they have in both cases locally reinforced the mountain against erosion, thus forming the »shoulders» of projecting ridges.

The surrounding sedimentaries of the Tung T'ai Shan area are represented by sandstones only, and shales have not been found. The sandstone is a green, very hard and dense variety (see Shih Tsun Shan

Series p. 105, and section A, Pl. III). It weathers sometimes to quite a bright grass-green colour and lies in regular banks up to a few m in thickness. The dip is locally 16° to 28° towards WNW.

The northern intrusive is also a typical neck of almost exactly the same rock composition as found in the southern one. The manner of intrusion has been the same in both cases.

Samples taken at numerous localities both centrally and marginally in both intrusives show remarkable uniformity. They appear as a light-coloured fine-grained rock (fig. 33) with bisilicates developed in irregular

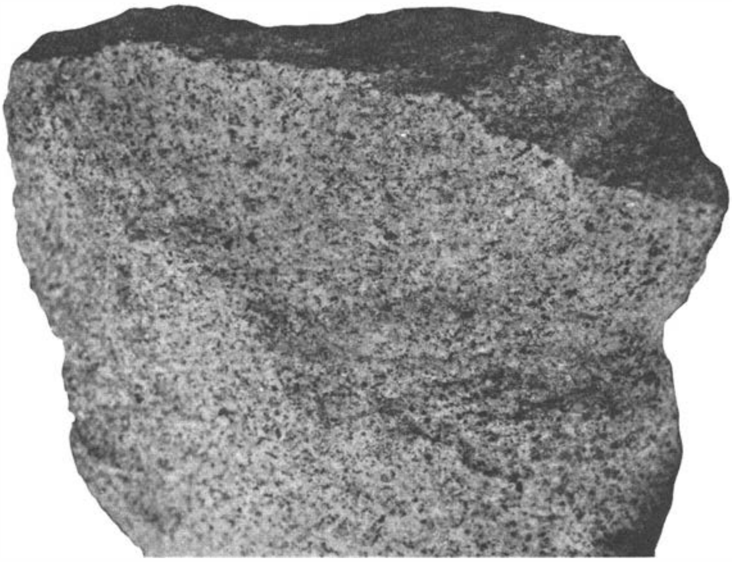

Fig. 33. Åkerite porphyry (1 : 1), No. V, Sample 321, from Tung T'ai Shan (Pan Shih Shan).

grains up to $1^1/_2$ mm in size but mostly smaller than that. The felspars appear at closer scrutiny as minute, glistening, lathshaped prisms. Weathering is light brown and not strong.

Under the microscope, fig. 34, the rock is seen to be hypidiomorphic porphyritic with closely packed small phenocrysts of potash-felspar and plagioclase in a groundmass of potash felspar, diopside, amphibole, a little quartz and accessory ore-grains, sphene, apatite and zircon, also some secondary calcite.

The potash-felspar phenocrysts are often perthitic and suggest tenure of sodium by their highly irregular, undulose or spotted extinction. The plagioclase phenocrysts are twinned according to the albite and pericline laws and are sometimes zonary. The composition of normal individuals is andesine ($Ab_{68}An_{32}$). They are not subordinate to the potash-felspar phenocrysts.

The felspar of the groundmass appears as grains of different size, the crystals are as a rule short, lath-shaped and interlocking with jagged edges; they contain much included substance in the shape of minute crystals of ore and bisilicates.

The pyroxene is a pale green diopside, sometimes altered to chlorite and epidote. More common than the pyroxene is amphibole, often in large irregular grains. Its optical properties indicate a common hornblende with extinction c : Z = 22°.

Quartz is present to an amount of about 1 % as interstitial substance.

A chemical analysis with calculations is given below (No. V, sample 321).

Table 5. Analysis of åkerite porphyry from Tung T'ai Shan, S. Shansi, by N. SAHLBOM.

S. G. — 2,69 (E. T. NYSTRÖM).

Analysis V		Mol. Prop.	Norm		NIGGLI's System	
SiO_2	57,70	962	Or	26,69	qz	−15
Al_2O_3	18,77	184	Ab	40,87	si'	194
Fe_2O_3	3,62	23	An	16,12	si	179
FeO	2,88	40	Σ sal	83,68	al	34,3
MgO	1,66	42	Di	7,72	fm	23,8
CaO	5,52	99	Hy	2,26	c	18,4
Na_2O	4,84	78	Mt	5,34	alk	23,4
K_2O	4,49	48	Ilm	0,61	k	0,38
H_2O	0,29	16	Ap	0,67	me	0,33
TiO_2	0,35	4	Σ fem	16,60	ti	0,7
P_2O_5	0,27	2	H_2O	0,29	p	0,4
MnO	0,08	1		100,57		
	100,47					
Moisture 0,21.						

Quantitative System — II : 5 : 2 : 3 — *Monzonose*

OSANN's System:	s	A	C	F	a	c	f	n	k
	64,4	8,4	3,9	11,1	7,1	3,4	9,5	6,2	0,93

Or : Ab : An — 31,9 : 48,8 : 19,3 MgO : CaO : FeO — 46,7 : 37,8 : 15,5

The microscopical and chemical examination classifies the rock as an *åkerite porphyry*, inclining towards monzonite. Compared with the åkerite of the Hu Yeh Shan (central Chiao Ch'eng area) this rock is characterised by less silica and the normative tenure of An is higher.

The dyke projecting from the western end of Pan Shih Shan is more porphyritic and richer in quartz and bisilicates than the main type. As for the rest the mineral composition is identical.

The northern stock shows a composition very similar to the main type described above, but containing more quartz and a little biotite, it is rather of nordmarkitic composition (cf. differentiation of the åkeritic parent magma of Lung Wang Miao p. 110).

The metamorphism caused by contact action of the Tung T'ai Shan intrusives on their surroundings is very inconsiderable. At the margin the sandstone, within a zone of a few cm width, has turned more quartz-

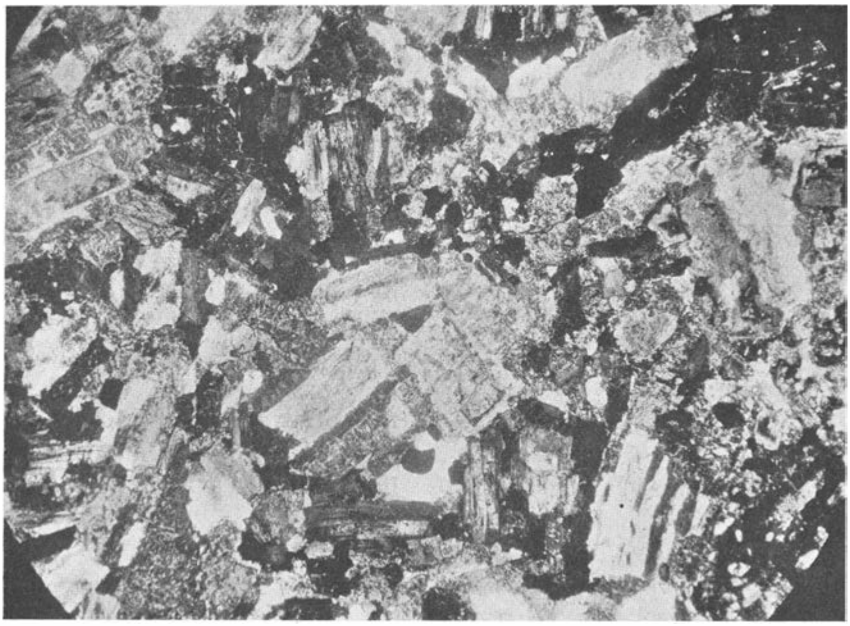

Fig. 34. Åkerite porphyry from Tung T'ai Shan (× 20, Nic. +).

itic without losing its green colour. Neither has the intrusive itself changed very much, no chilled margin being observed. A notable fact is the absence at the contact of breccia and inclusions of side-rock in the igneous mass both facts indicating that the magma has been flowing for a long period through this channel. The emplacement of these two necks and the above stated observations suggest that here are exposed sections of deepseated channels which have supplied material for a superimposed laccolith or volcano.

The Shih Tsun Shan Intrusive. Shih Tsun Shan is a small isolated hill about 20 km SE of P'ing Yang Fu and 10 km NNE of Tung T'ai Shan. The main mass of the hill is of compact green sandstone (see section A, Pl. III). In the centre is a dyke which cuts through the sediments at a steep angle. The rock is a facies of the Tung T'ai Shan åkerite but more plainly porphyritic. When fresh it is greyish green with pink felspar phenocrysts of different size up to 4 by 5 mm irregularly scattered throughout. Very small greenish crystals of bisilicates occur sparsely. Under the microscope the mineral composition is seen to be very similar to that of the Tung T'ai Shan intrusives, but the potash felspar is seen to be more conspicuously perthitic and plagioclase less in quantity, often included as cores in the orthoclase. The pyroxene is an aegirine-augite, the quantity is small. There is also a little quartz. The rock may be classified as an åkerite porphyry.

The Liang Chia P'o Intrusive. In 1922 the P'ing Yang region was visited by C. C. WANG of the Geological Survey in Peking. He found just south of the village Kuan Ch'iao at the main road between P'ing Yang Fu and Fou Shan Hsien a round neck-like intrusive adjoining the village Liang Chia P'o. This place is situated 50 li or 25 km E 30° S of P'ing Yang Fu and 10 km NNE of Shih Tsun Shan (cf. map, fig. 1). A sample of the intrusive rock was brought back by C. C. WANG and examined by L. F. YIH of the Survey, who classified it as an analcite-syenite porphyry (cf. YIH 33). As no map or detailed petrographic examination had been done in the field it was found desirable that the writer should proceed there, and this was done in Febr. 1925. I am indebted to my assistants Messrs SUN, TSAO and CHANG for topographical work done here. Excursions to the south from Liang Chia P'o led to the discovery of Tung T'ai Shan, Lung Wang Miao and other intrusives.

It is a notable fact that the northern as well as the southern end of the intrabasinal range of the P'ing Yang depression mentioned above, p. 101, is marked by intrusions the former being the Liang Chia P'o and the latter the Tung T'ai Shan area.

Kuan Ch'iao village (see above) lies on a plateau of very thick loess and nothing else is visible from the main road. But proceeding about one km southwestwards we find the loess deeply dissected and parts of the rocky foundation exposed. It is here that the Liang Chia P'o intrusive is situated and the loess is so thick that one actually looks down from it on the knolls of igneous rock.

The largest exposure is towards west at the hamlet Liang Chia P'o (see map. fig. 35). The centre and eastern parts are largely loess-covered except a small part of the south-eastern margin. Before the loess was deposited, erosion had sculptured out the intrusive so as to form a low eminence with three peaks at a few hundred m distance from each others. This erosion has been renewed, since ravines are seen to follow the margin of the intrusive. Through the southern part of the field a small river is

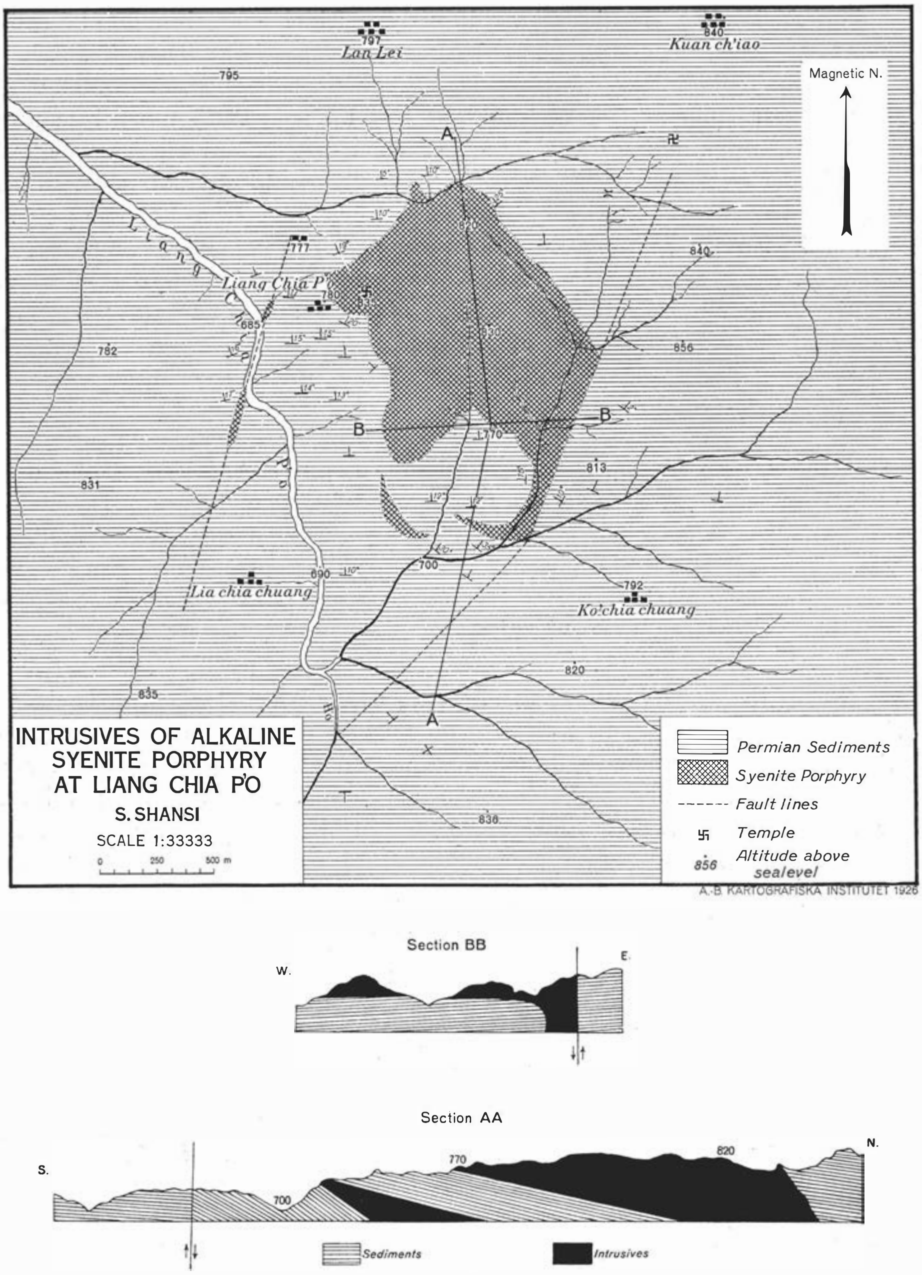

Fig. 35. The Liang Chia P'o Intrusives.

running westwards with a permanent flow. Its course is sometimes canyon-like. For some distance it follows the faultline existing in the southwestern corner of the mapped area.

The character of the surrounding sediments were assumed by C. C. WANG to be of »Permo-Mesozoic» age. But the immediate surroundings are different in the east and west part of the field, because a faultline runs between these parts. The western sediments consist of a series of gently dipping banks of alternate yellow-green sandstone and dark shale, in rather thin regular layers from a few dm to some m in thickness. The eastern field which probably exposes older rocks (the intrusive being on the sunken side as usual) consists of gently dipping alternate layers of dark purple shale and finegrained grey or purple sandstone, the whole coloured purple by débris from the shale. The layers are up to a few m in thickness. No fossils were found but this series reminds one strongly of the »chocolate-coloured» Permian Shih Ch'ien Feng series described by NORIN (18) from central Shansi. The sediments adjoining the intrusive are probably younger, but still Permian.

The dip of the neighbouring sediments has been somewhat affected by the action of the intrusive, but there is no proper up-arching like that near the margin of a laccolith.

Regarding the emplacement of this intrusive mass it is observed that the eastern contact is nearly vertical (see section B—B, fig. 35) and runs very straight in the normal direction of the Ho Shan fault-line (cf. p. 101) viz. NNE—SSW. Also in the north a vertical contact is exposed, but the north-eastern boundary is largely concealed by loess. Along the southern and south-western border the sediments are seen dipping flatly in under the igneous body. The tectonics and emplacement of this body coincide in a remarkable way with the conditions prevailing at Tzu Chin Shan in western Shansi (see Chap. IV), a similarity which even extends to the general configuration on the map. The eruptives exposed at Liang Chia P'o seem to represent two thick sills or »tongues» which are conformable with the sediments and originate from a stock or dyke which has erupted along the eastern fault-line. In confirmation of this we find that outside the western border of the massif a dyke penetrates the sediments along a minor faultline parallel with the above-mentioned one.

Judging, from samples taken in nearly all available places, the petrographic character of the Liang Chia P'o intrusive is remarkably uniform. Only in the SE corner are there signs of slight differentiation. Here also a conspicuous cleavage is observed, the rock mass being parted in rather thin layers with dip locally 50° towards SW.

A rock sample from this intrusive was first described by L. F. YIH (33) who published a preliminary report. In connection with the mapping of the area and the chemical examination of the rock a fuller description is now given.

The main rock type (fig. 36) is of a light flesh-coloured tint with perhaps an inclination towards violet colour. The structure is plainly porphyritic with phenocrysts of whitish grey felspar up to 30 mm in size in a very finegrained groundmass. Prismatic crystals of bisilicates up to a few mm in size are somewhat regularly distributed throughout. Analcite is seen in the groundmass by the naked eye as a quartz-like, glass-clear mineral. Weathering is rather deep and whitish.

Under the microscope we find (fig. 37) a porphyritic, partly fluxion-structured rock with phenocrysts of two kinds of felspars and bisilicates in a very fine-grained (0.09—0.2 mm) groundmass of alkali-felspar, aegirine-augite and a few grains of ore, zircon, sphene and apatite and as secondary minerals: analcite, epidote and calcite. The felspar phenocrysts are

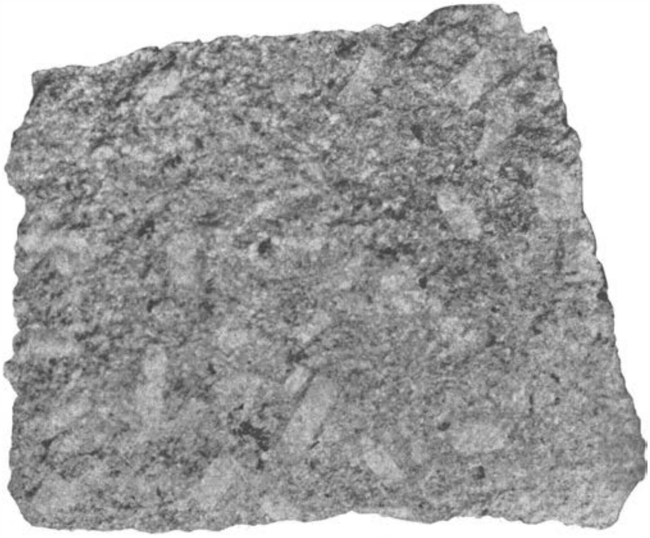

Fig. 36. Analcitised aegirine-augite-syenite porphyry (1 : 1), No. VI, Sample 301, from Liang Chia P'o.

oligoclase-albite and a slightly sodic orthoclase in about equal quantities. The plagioclase sometimes forms the core of the orthoclase phenocrysts.

The pyroxene occurs in scattered crystals up to 5 mm in size but generally in minute grains. It is very subordinate. Absorption colours are:

X — olive to grass green
Y — pure green
Z — wine yellow
$X \geqslant Y > Z$.

Extinction $c:Z = 56°$. It is an augite inclining towards aegirine-augite and is very little decomposed.

The most remarkable constituents of the rock are the secondary

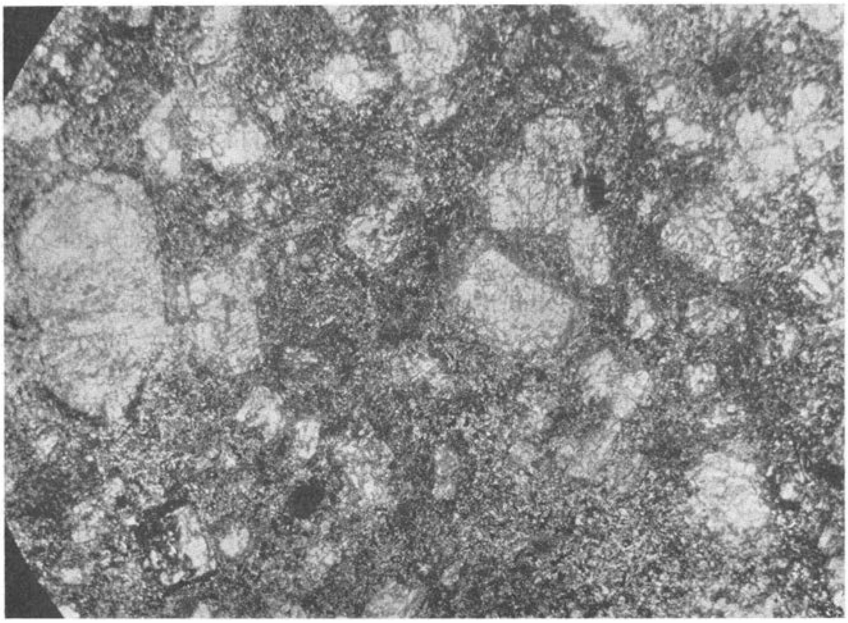

Fig. 37. Microphoto (× 11, Nic. +) of sample 301.

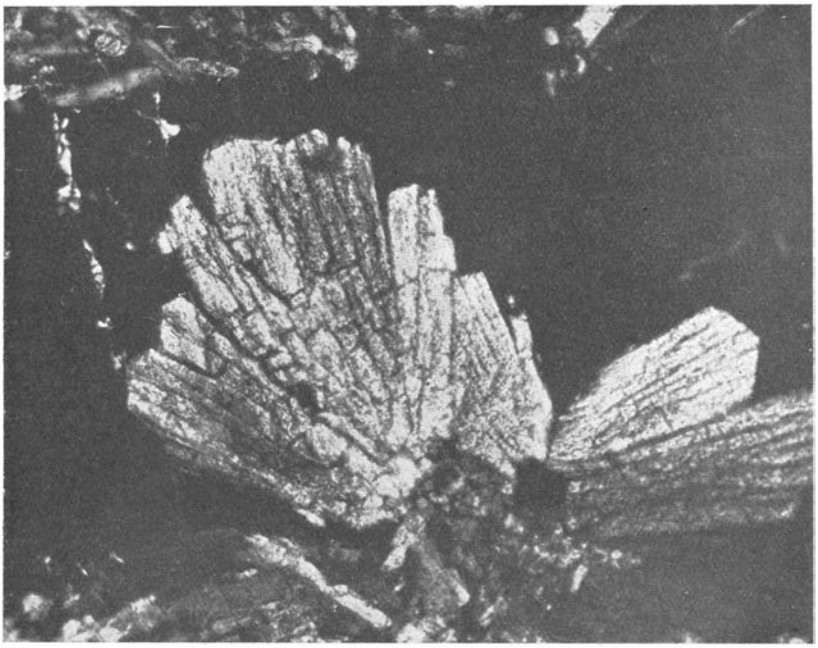

Fig. 38. Epidote rosettes (× 240, Nic. +) grown from walls of cavities now filled with analcite. In sample 301.

minerals analcite and epidote. The former occurs mainly as alteration product in patches inside the felspar phenocrysts and as filling in miarolithic cavities into which the epidote protrudes as idiomorphic rosettes (fig. 38). It is to be mentioned that the felspar phenocrysts apart from the analcitised portions are perfectly fresh. — The analcite looks clear and glass-like in ordinary light, has fracture lines rather than cleavage at more or less right angles and is perfectly isotropic. Heated by the blowpipe it fuses to a white glass (L. F. YIH). Chemical examination of this rock showed only traces of Cl and SO_3. This observation combined with the high water content of the mineral and the microscopical examination identify it as analcite. The epidote appears, as mentioned above, in rosettes or detached crystals in the cavities filled by analcite and is therefore of earlier generation. Its colour is pale greenish yellow with only slight pleochroism. It is sometimes zonary with pink tips. Calcite occurs interstitially together with the other secondary minerals.

This rock is an *aegirine-augite-syenite porphyry* which has been analcitised through pneumatolytic action. A chemical analysis with calculation is given below (No. IV, sample 301).

Table 6. Analysis of analcitised aegirine-augite-syenite porphyry from Liang Chia P'o, S. Shansi, by N. SAHLBOM.

S. G. — 2,49 (E. T. NYSTRÖM).

Analysis IV		Mol. Prop.	Norm		NIGGLI's System	
SiO_2	60,57	1010	Qu	0,42	qz	−6
Al_2O_3	19,98	196	Or	38,36	si′	238
Fe_2O_3	1,76	11	Ab	42,44	si	232
FeO	0,60	8	An	12,23	al	45
MgO	0,61	15	C	0,20	fm	10,6
CaO	2,44	44	Σ sal	93,65	c	10
Na_2O	5,04	81	$MgSiO_3$	1,50	alk	34,4
K_2O	6,53	69	Mt	0,93	k	0,46
H_2O	2,32	129	Hem	1,12	mg	0,33
TiO_2	0,35	4	Ilm	0,61	h	29,6
P_2O_5	0,03	0	Pyr	0,12	ti	0,9
S	0,05	2	Σ fem	4,28		
MnO	0,07	1	H_2O	2,32		
	100,35			100,25		

Quantitative System — 1 : 5 : 2 : 3 — *Pulaskose*

OSANN's System:	s	A	C	F	a	c	f	n	k
	69,9	10,4	3,1	3,1	12,5	3,8	3,7	5,4	0,98

Or : Ab : An — 41,2 : 45,6 : 13,2; MgO : CaO : FeO — 100 : 0 : 0

The high content of alumina and water is no doubt caused by the presence of analcite. The percentage of potassium is higher than in any of the other analysed rocks. For further discussion see Chap. V.

There has been very little differentiation in the Liang Chia P'o intrusive, the rock composition being on the whole remarkably uniform. Perhaps a slight change is noticeable towards the NW corner, where a sample taken at the millstone quarry here located, shows slightly darker colour and under the microscope almost universal analcitisation of the felspars. There is more of ore-grains and more decomposition, that is all.

The south-eastern part is also slightly different from the main type. The rock is here a pure light grey (not pinkish like the normal one) with very little bisilicate. The white weathering coat, about $^1/_2$ mm thick, is often stained black by growth of lichens making the outcrops easily visible in the field. Microscopically the difference to the normal type is inconsiderable and analcite is present also here. Decomposition is less pronounced and this may account for absence of pink colour.

A dyke in the south-western corner of the area seems to be petrographically similar to the main intrusive but is so weathered that a microscopical examination would be of little avail.

The contact features of the Liang Chia P'o intrusive are on the whole very unimportant. The igneous rock, within $^1/_2$ m from the contact, seems to undergo a change of colour to more brown-red and the sediments, if sandstone, to more greenish yellow. In shale the action seems to have penetrated further (perhaps through pneumatolytic action), as there is a zone, say 2 m wide at 7 m distance from the contact, which zone has changed colour to yellow-green. The nature of these colour changes has not been investigated.

In the river-bed just south of the intrusive boulders of Cambro-Ordovician limestone and other sediments are found, but also different types of volcanic rocks. These latter may originate from the Lung Wang Miao intrusive (see Chap. II) or from some still undiscovered intrusive towards south-east. The former supposition is more likely as rocks have been found here similar to the boulders in the Po P'i Ho river bed (see p. 100) at Tung T'ai Shan which boulders were found to come from the Lung Wang Miao area.

Regarding age and history of the Liang Chia P'o intrusion there is little doubt that it occurred at the time of formation of the Fen Ho graben and this will be more fully discussed in Chap. VI, which will deal in generally with the age of the Shansi alkaline rocks.

IV. Tzu Chin Shan.

Apart from above described areas of alkaline rocks in Shansi yet another is known and has been examined by E. NORIN (17). Characteristic for Tzu Chin Shan are several features which are not met with in the other alkaline areas.

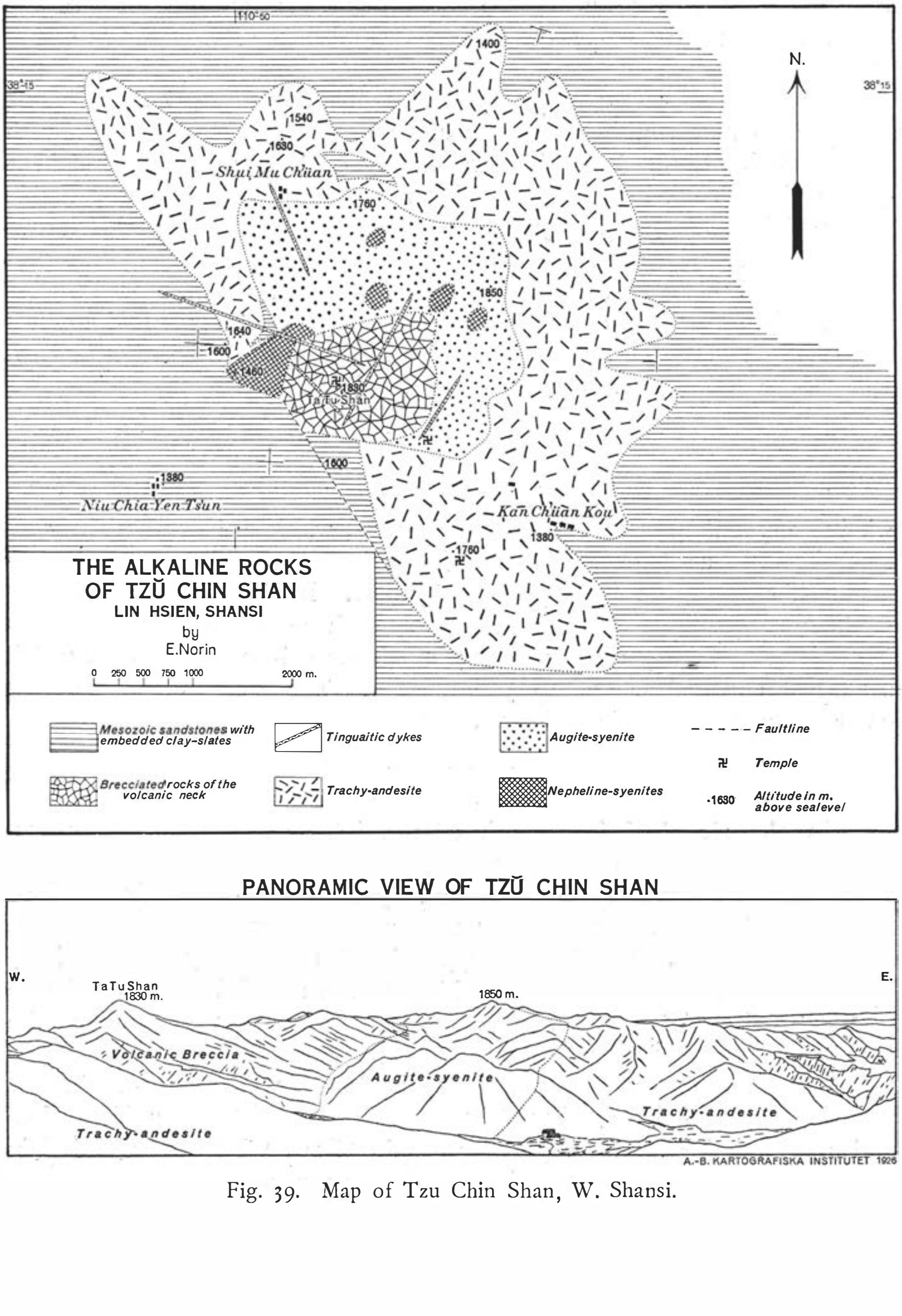

Fig. 39. Map of Tzu Chin Shan, W. Shansi.

Therefore, before entering upon the comparative study of the Shansi alkaline rocks, it will be necessary briefly to dwell upon the tectonics and main petrographic features of Tzu Chin Shan and a résumé of NORIN'S paper (17) is given below.[1]

Tzu Chin Shan is situated in westernmost Shansi 20 km NNW of Lin Hsien town, at 110° 51′ E and 38° 14′ N. It forms a small isolated mountain group which rises in numerous peaks alone and unexpectedly from the surrounding vast mesozoic sandstone plateau (cf. map fig. 39).

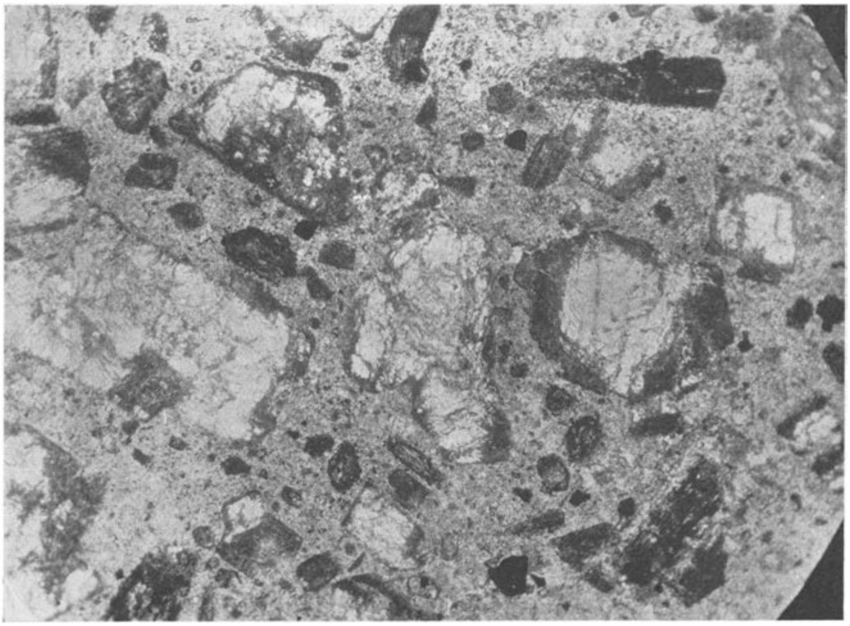

Fig. 40. Åkerite porphyry from Tzu Chin Shan (× 23, Nic. 11).

The area is composed of alkali-syenitic rocks which have been intruded in the shape of a laccolith at shallow depth below an old land-surface. The laccolith has formed the *reservoir* to a superimposed volcano, of which part of the crater-pipe is till preserved and which forms, in the shape of a neck, the second highest peak of the massif.

The igneous rocks, which have been laid bare, occupy a triangular area of approximately 15 sq. km. (see map, fig. 39). The highest peak reaches an altitude above sea-level of 1,850 m (aneroid measurement); the map indicates emplacement and distribution of the rocks.

In a preliminary way, these have been divided in the following groups: åkerite porphyry (first called by NORIN trachy-andesite), augite-syenite, intermediary nepheline-syenites and nepheline-aegirine-syenite. This order also indicates the sequence of eruption.

[1] Fig. 40—48 are photographs newly taken and do not occur in NORIN'S paper.

The åkerite porphyry is exclusively found in the peripheric parts of the area. It ressembles in hand-specimens a grey medium-grained monzonite with closely distributed white idiomorphic felspar phenocrysts and small black prisms of bisilicates. Under the microscope (fig. 40) are seen: phenocrysts of andesine ($Ab_{56} An_{44}$), alkali felspar, a green hornblende, pyroxene, sphene, apatite and oxygenated ore-minerals in a holocrystalline fine-grained to dense groundmass of oligoclase, alkali felspar, opaque ore-grains and a little quartz, furthermore secondary mineral products: abundant epidote, chlorite, quartz, opal and pyritic minerals. The phenocrysts dominate distinctly in relation to the groundmass.

The augite-syenite is the most interesting rock in the massif because with it is connected a number of types varying from alkali-lam-

Fig. 41. Augite-syenite (1 : 1) from Tzu Chin Shan.

prophyre to pure nepheline-syenite. Contrary to the åkerite porphyry the augite-syenite is a rock of abyssic character, nepheline-bearing and poor in lime. A glance at the map shows its distribution. It occupies the central part of the region and is surrounded on all sides by the åkerite porphyry, except towards SW where it borders on the sedimentary rocks.

In typical development the augite syenite (fig. 41) is a finegrained to mediumgrained rock rich in dark minerals and shows a glassy surface with peculiar bluish tint. Under the microscope (fig. 42) it is seen to be of hypidiomorphic granular structure built up of alkali felspar, nepheline, aegirine-augite, alkali-amphibole, sphene, opaque ore-minerals, apatite and secondary zeolite products. A primary sodalite mineral is also observed.

The intermediary nepheline-syenites. These are transition types between the fully developed nepheline-aegirine-syenite and the mediumgrained augite-syenites and seem to originate through a more or less advanced differentiation of the original magma. Few of these rocks occur with any degree of uniformity over large areas.

The main type is a slightly protoclastic coarse-grained rock with peculiar oolithic structure which is caused by the arrangement of the dark minerals in and around the felspar. The examined type shows the following mineral association: alkali-felspar, nepheline, aegirine-augite, biotite, magnesia-spinel[1], sphene, iron ore, pyritic minerals, apatite and the secondary minerals natrolite and analcite. As a singular fact may be mentioned

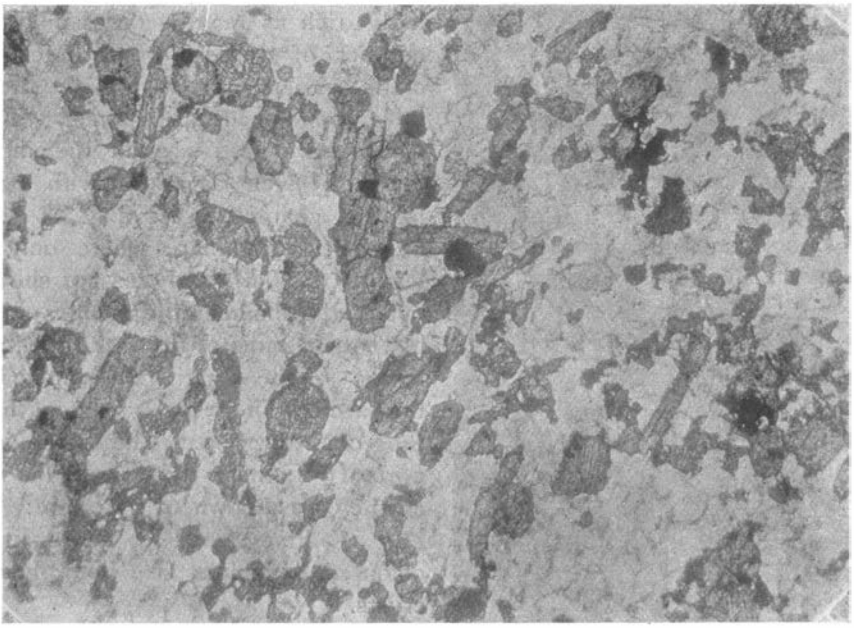

Fig. 42. Microphoto (× 13, Nic. 11) of augite-syenite, fig. 41.

that a not inconsiderable proportion of nepheline enters in crystallographically orientated intergrowth with felspar.

One of the most interesting features of this rock-type is its structural development. Macroscopically it is visible especially in light-coloured types, which appear as if they were built up of close-lying rounded or oval felspar individuals of pea-size pasted together by dark minerals. Sometimes they show a rounded rhomboedric longitudinal section and the rock becómes then not unlike a nepheline »rhomb-porphyry».

The nepheline-aegirine-syenite occurs typically and fully developed within a small area in a valley immediately west of point 1830 (Ta Tu Shan). Its geological occurrence indicates that it is only a small outcrop of a larger mass existing at greater depths.

[1] Closer examination makes it probable that this is melanite (E. T. N.).

The main coarse type is often miarolithic with large reflecting prisms of pearlgrey felspar, rounded crystals of greasy-looking redbrown nepheline and sparse crystals of dark bisilicates which sometimes unite to larger aggregates. Typical is the nepheline-weathering (fig. 43). The principal type shows the following mineral association: alkali-felspar, nepheline, aegirine, biotite, apatite and small quantities of secondary minerals, mainly natrolite. Sphene has not been observed.

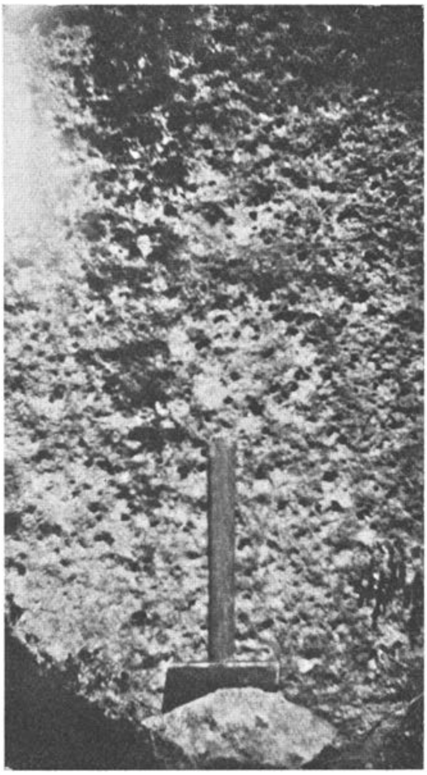

Fig. 43. Typical weathering of nepheline-aegirine-syenite, Tzu Chin Shan.

The association of dyke rocks of the nepheline-syenites is exceedingly rich as regards types and the number of dykes is great. Melanocratic varieties belonging to these have not been ascertained. The leucocratic types are all the more frequent, even as rocks with pegmatitic character. As may be seen on the sketch map, where only a few of the larger dykes are shown out of the innumerable number existing, they radiate from the central region of the massif represented by the neck. They are younger than the crater-breccia. The most important of these dyke rocks (as far as they are known to date) are:

1) Finegrained to dense, light coloured tinguaites, free from phenocrysts.

2) Similar tinguaites, but with phenocrysts of sanidine.

3) Tinguaites with phenocrysts of nepheline and sanidine.

4) Tinguaites with phenocrysts of pseudo-leucite (fig. 44, 45 and 46).

5) Leucite syenite porphyry.

6) Finegrained dark dyke rocks of tinguaitic character.

7) Syenite pegmatites of several different types.

The volcanic neck. Ta Tu Shan (see map point 1830) is developed in steep declivities with numerous caves (fig. 47) and represents the central part of the volcanic neck. On a wide circumference the surrounding syenite rocks are strongly brecciated, and intruding gases and solutions have caused an often far-reaching decomposition of the fragmental rocks (fig. 48) and filled the crevices with secondary minerals such as fluorspar, calcite and iron-ore. The border zone is marked by specially easy erosion (valleys).

Towards the more central part of the neck eruptive material begins to enter the composition of the breccia, filling up the fissures and cementing the whole to a very tough and solid rock. The fragments are here in a better state of preservation. Usually the cement has the character of a hypabyssic, lightcoloured felspathic rock but it is sometimes also plainly trachytic.

Summarizing the features of Tzu Chin Shan it is seen that all the rocks belong to the alkaline family. The oldest intrusion which appears as åkerite porphyry is in comparison with the younger one remarkable for its high tenure of lime (plagioclase). A chemical analysis will probably characterize this rock as being of a composition similar to the åkerite of

Fig. 44. Leucite-tinguaite (1:1) from Tzu Chin Shan.

Hu Yeh Shan (No. I, sample 172) the supposed parent rock of the central Chiao Ch'eng intrusives (cf. p. 83). Possibly this rock is a hypabyssic facies of the deep seated primary rock which has given origin to the augite-syenite through differentiation.

Contrary to the åkerite porphyry the succeeding augite-syenitic magma is poorer in silica and richer in alkalis and magnesia which latter with almost all the lime, sesquioxides and a little alkali were instrumental in forming pyroxene. Lime-soda-felspar is missing. Both the above mentioned rocks are rich in sphene.

The process of differentiation within the augite-syenite is easier to follow. Towards the basic pole the differentiation has resulted in lamprophyric rocks rich in magnesia and lime, poor in alkalis and free from

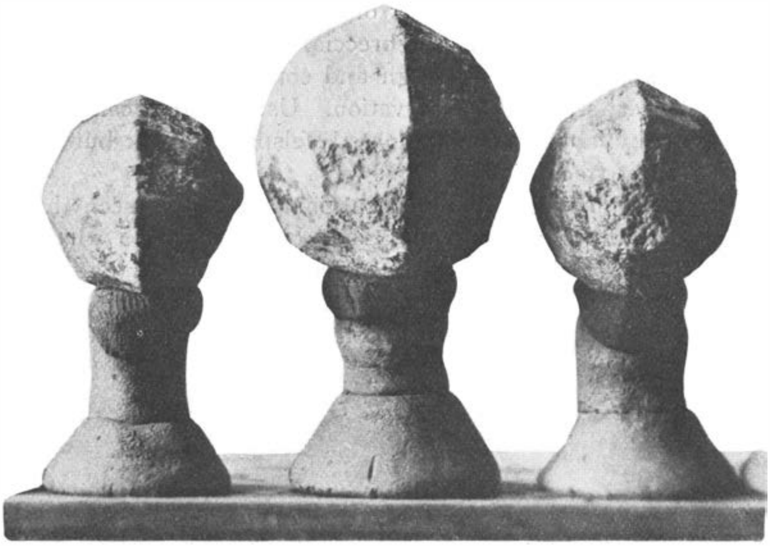

Fig. 45. Phenocrysts (1: 1) of pseudo-leucite, weathered out of rock, fig. 44.

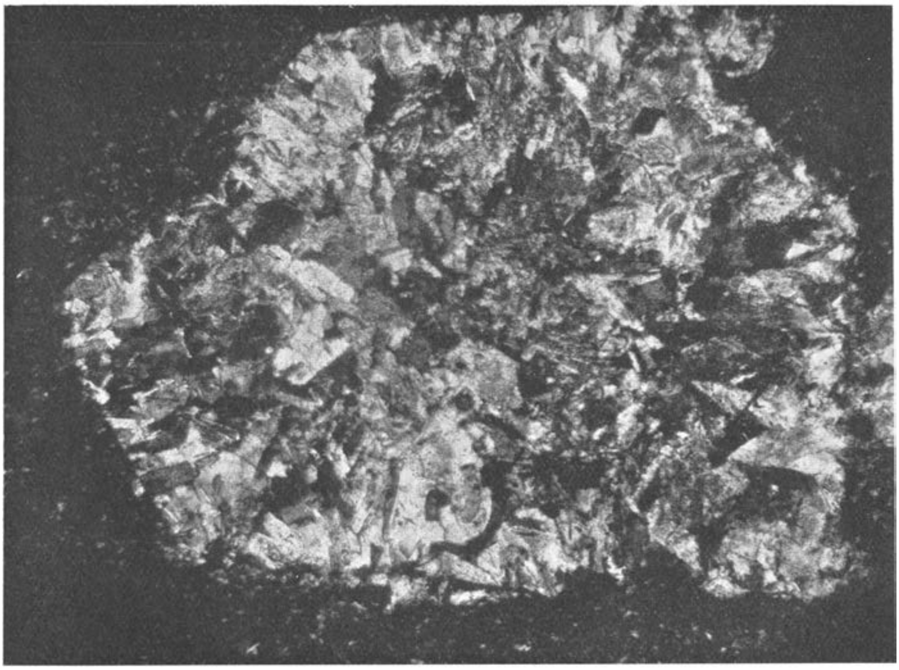

Fig. 46. Microphoto (× 20, Nic. +) showing structure of pseudo-leucite phenocrysts.

sphene. — The intermediary nepheline-syenite, which has possibly segregated from the augite-syenite, is poorer in silica and dark bisilicates than the parent rock. The tenure of alkali is comparatively larger, which has found expression partly in more abundant production of nepheline, partly it has augmented the aegirine molecules of the pyroxene. The tenure of sphene is nearly unchanged. This rock is no constant type, but represents probably a stage fixed through intervening solidification.

A differentiation which has been carried still further has resulted in a nepheline-syenite entirely composed of minerals rich in alkalies.

Also within the nepheline syenite magma processes of differentiation have been active which have led to a partial separation of the alkali

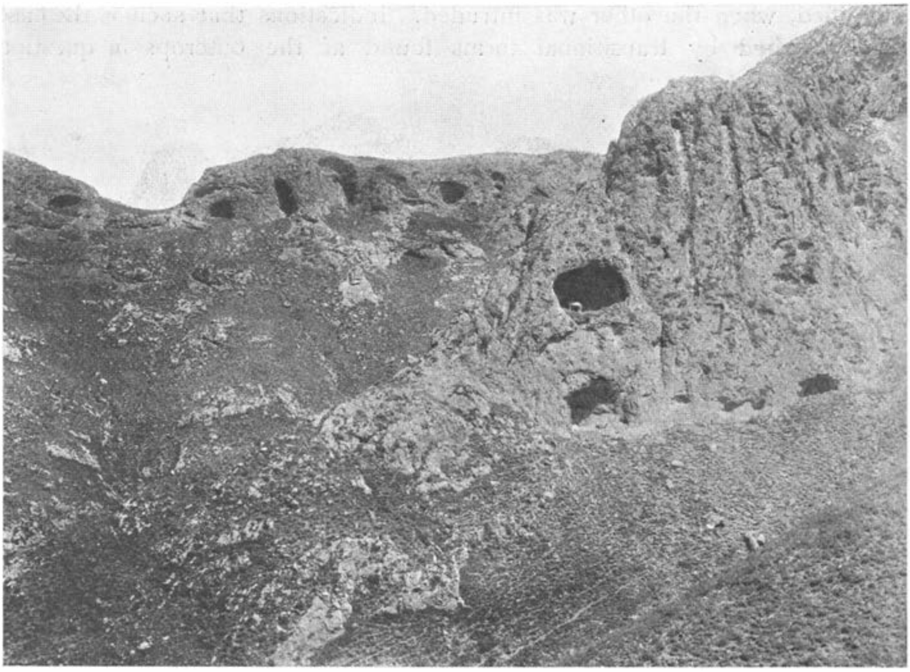

Fig. 47. The Volcanic Neck of Tzu Chin Shan.

metals. This parting reveals itself in development of sodium-predominant and potassium-predominant rocks, represented by nepheline-bearing and leucite-bearing tinguaites.

V. Evolution of the Shansi Alkaline Rocks.

Sequence of eruption. The chronology of intrusion within the Chiao Ch'eng area is to a certain degree analogous with that of Tzu Chin Shan. Also here the first intrusion is of åkeritic composition and has been injected in the form of a large laccolith — the Hu Yeh Shan igneous body. Regarding the neighbouring massif of Ch'i Huo Ch'i Tung, I have been unable to state the time of intrusion of this nordmarkitic magma in relation to the Hu Yeh Shan åkerite, because, on account of heavy covering of débris, field-observations have not been possible at the only place where a chronological sequence might be obtained, viz. one km north of Lung Ch'uang Kou, where the massif of Ch'i Huo Ch'i Tung borders upon the sills of Hu Yeh Shan. In the outcrops available near the supposed contact, no eruptive breccia has been observed, nor have inclusions of one rock in another been noticed. It is possible that there is a gradual transition between the åkeritic and nordmarkitic rocks, owing to the fact that the one (probably the åkerite) was not fully solidified, when the other was intruded. Indications that such is the case are furnished by transitional forms found at the outcrops in question (cf. p. 86).

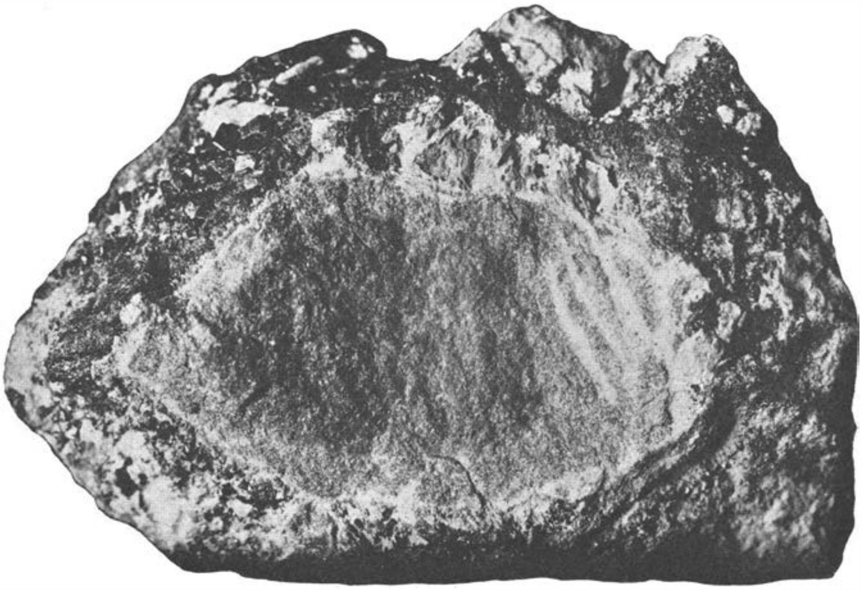

Fig. 48. Fragment of volcanic agglomerate, neck of Tzu Chin Shan.

While thus the difference in age between åkerite and nordmarkite is probably inconsiderable, the hiatus in time between these and the next principal intrusions, viz. the aegirine-augite-syenites is very great. During this hiatus the important dislocations took place whereby the northern rim of the Hu Yeh Shan laccolith was broken and the tilting of the northern blocks took place. After this stage the aegirine-augite-syenites were intruded in the shape of stocks. They cut across the older laccoliths and penetrate to a higher level in the sedimentary series, where they have extended, forming a sill or another laccolith to which the remnants on top of Hu Yeh Shan may belong.

The intrusives in south Shansi also indicate a similar sequence of events. The oldest and principal rocks are of åkeritic composition, intruded in an anticlinal fold. At a later stage, but before the main type had completely solidified, a series af derivatives, ranging between banatite porphyry and quartz porphyry, were intruded. Within the main igneous body of Lung Wang Miao aegirine-augite-syenites corresponding to those of the northern area have not been observed, but in the neighbourhood satellites of such composition have been discovered (the Tung Ta'i Shan, Shih Tsun Shan and Liang Chia P'o intrusives). Although these are not connected in the field with the main body, yet the petrographical character of the rocks and their similarity to corresponding differentiates in the Chiao Ch'eng and Tzu Chin Shan areas makes it highly probable that they are genetically connected with the Lung Wang Miao magma.

Favourite horizons. In the Chiao Ch'eng district the laccolithic intrusions of åkeritic character are found only within the upper part of the Cambro-Ordovician limestone, whereas they are absent at higher levels of the sedimentary series. On the other hand laccoliths of more pronounced alkali-syenitic composition are confined to the Permo-Carboniferous series. Thus the relic of laccolithic intrusion at Tung Hsien is of much more alkaline character than the main laccolith below.

Also in the P'ing Yang area in south Shansi the main laccolithic intrusive chiefly of åkeritic character is found in an anticline of Ordovician limestone, whereas at this horizon laccolithic intrusions of highly alkaline rocks are seldom to be found. These latter occur as dykes, necks or chonoliths.

The three igneous areas above described may be interpreted as representing three separate planes laid through the same eruptive formation at different levels. The uppermost level, which is laid quite close to the ancient land-surface, is represented by Tzu Chin Shan. The lowermost section represented by the Hu Yeh Shan and the Lung Wang Miao igneous bodies, is laid through the fundamental laccolith. The middle plane is represented by sections through the stocks described at Tung and Hsi Kuang T'a Men.

The laccolith of Tzu Chin Shan is situated in the upper Palaeozoic or Mesozoic and is separated from the Ordovician limestone by a very thick series of continental sediments. The åkeritic body of this locality is of very modest dimensions and it is impossible that from this inconsiderable bulk the alkaline magmas could have issued. Moreover, the åkerite has crystallized in a hypabyssic manner, whereas the alkaline magmas have formed abyssic-looking rocks. This proves that a more large and deep-seated source must be looked for, wherein the alkaline magmas could have been able to differentiate from the åkerite. Exactly to locate this reservoir is not possible, but it may be assumed to exist at the same horizon as in Chiao Ch'eng and Lung Wang Miao, viz. in the upper part of the Ordovician limestone.

Comparative petrology. Although separated by considerable distances, the Shansi alkaline rocks exhibit, with regard to certain fundamental characteristics a striking similarity. The »parent magma» in each of the three districts under discussion shows both macroscopically and microscopically a close relationship. The åkerite-porphyry of Tzu Chin Shan, the åkerites of the large laccoliths of Chiao Ch'eng and Lung Wang Miao are practically identical (see petrographic descriptions p. 82, 108 and 130). Moreover, the slightly differentiated north-eastern rocks of Chiao Ch'eng and some of the rocks pertaining to the P'ing Yang basin intrusives, can scarcely be distinguished in handspecimens.

In the diagram, fig. 49, the main types of rocks characteristic for the Tzu Chin Shan, Chiao Ch'eng and P'ing Yang areas have been systematically arranged. For each area the derivatives have been arranged along three stems representing from left to right the granitic, syenitic and dioritic differentiation. In all the areas the åkerite has been assumed to be the parent magma. The lines 1—5 indicate the age-relation between the different injections. Tzu Chin Shan is exceptional inasmuch that it is the only area in which nepheline and leucite-bearing derivatives are known to exist.

As mentioned above, the laccolithic intrusions in the Ordovician limestone are in all three areas of åkeritic character. Table 7 below shows the mineral composition of these three rocks:

Table 7.

Group I. Åkerites.

Mineral Composition	Chiao Cheng (Hu Yeh Shan)	P'ing Yang (Lung Wang Miao)	Tzu Chin Shan
Quartz	x	x	x
Alkali-felspar	XX	XX	XX
Plagioclase	XX ($Ab_{65}An_{35}$)	XX ($Ab_{68}An_{32}$)	XXX ($Ab_{56}An_{44}$)
Pyroxene	xx	x	x
Amhibole	x (common hornbl.)	x (common horn.)	x (alkali)
Biotite	—	x	—
Sphene	x	x	x
Ore	x	x	x
Apatite	—	x	x
Structure	Hyp-Abyssic	Hyp-Abyssic	Hyp-Abyssic

It is seen that the åkeritic rocks from all three areas contain orthoclase (sodic) and this is mostly perthitic, often beautifully so. Plagioclase varies between oligoclase-albite and andesine, but these two extremes are rare, and it is often nearest to oligoclase-andesine (typical plagioclase of monzonite-inclined syenites). Ferro-magnesian minerals are pyroxene, grading from diopside to aegirine-augite, and hornblende. Quartz is generally present but in the undifferentiated rock it is of small quantity. Accessory minerals are rather constant and are: ore, sphene and apatite, biotite is mostly scarce.

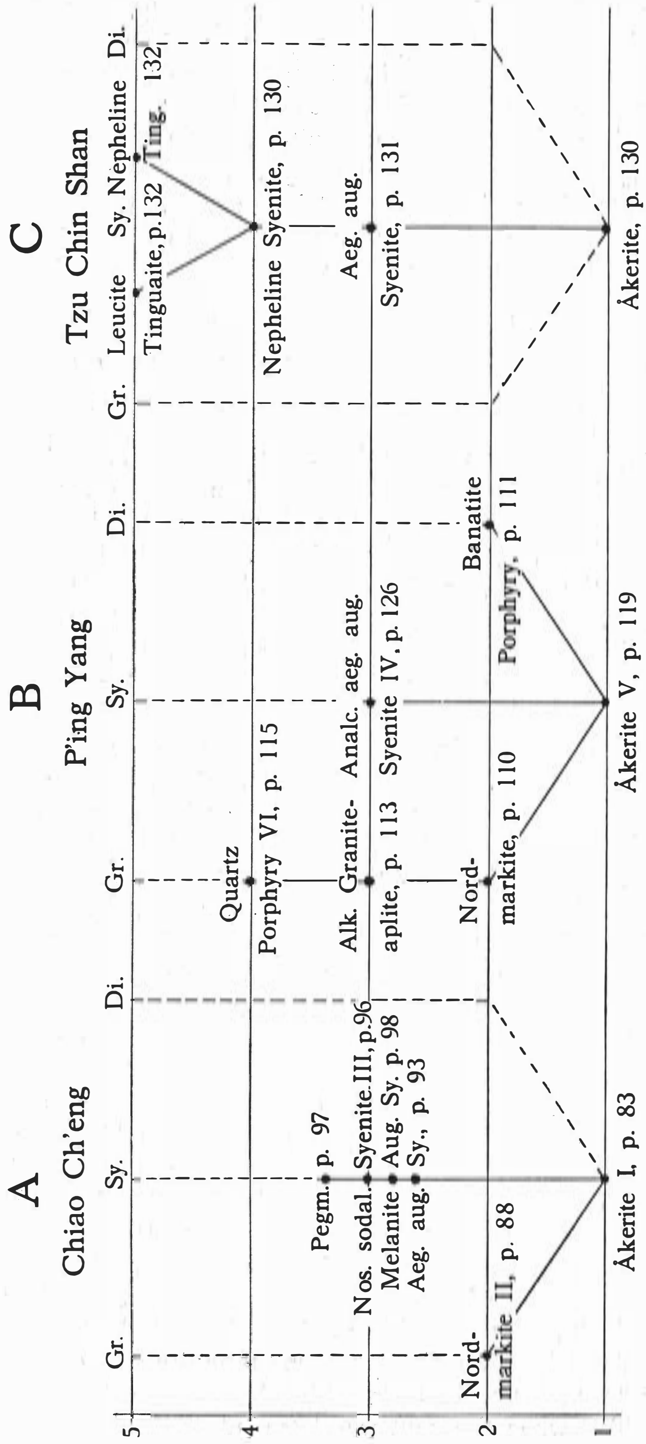

Fig. 49. Differentiation along the granitic (Gr.), syenitic (Sy.) and dioritic (Di.) stems in Chiao Ch'eng, P'ing Yang and Tzu Chin Shan.

In the combined table 8 of chemical analyses (p. 141) those Shansi åkerites which have been analysed appear in Group 1 and for comparison's sake two analyses of åkerite-types from the Christiania (Oslo) field have also been entered. The chemical examination characterises the Shansi åkerites as typical sodium-syenites with tenure of alkali=9—10 % and with Na_2O predominating over K_2O. Also with regard to silica, sesquioxides and lime the agreement is apparent. Compared with the standard type of monzonite syenites according to NIGGLI's system (see note p. 83) the conditions are as follows:

	qz	si'	si	al	fm	c	alk	k	mg	ti	p
Average of Shansi åkerites:	8	203	195	32,8	22,5	18,9	25,7	0,37	0,28	1	0,4
NIGGLI's type of monzonite syenite	—	—	190	37	23	14	26	0,50	0,35	—	—

In their type-locality which is the Christiania (Oslo) field (cf. BRØGGER 4 and 5) the åkerites are rocks of hypidiomorphic grain or trachytic structure, composed of alkali felspar with cores of plagioclase, diopsidic pyroxene and biotite. Quartz is subordinate. The only difference between this type and the Shansi rocks seems to be the fact that in the latter the plagioclase, besides occurring as cores, also exist as independent individuals. Chemically as well as mineralogically it seems appropriate to classify the Shansi rocks under discussion as åkerites and åkerite porphyries.

It may be assumed that the rich variety of other alkaline rocks in Tzu Chin Shan, Chiao Ch'eng and P'ing Yang have issued as differentiation products from a parent magma of more or less åkeritic composition. It is believed that only in the P'ing Yang area it has been possible to trace a differentiation along all thre of the stems mentioned above, viz. the granitic, syenitic and dioritic stem (cf. fig. 49). In Chiao Ch'eng the granitic and syenitic stems are the only ones observed. In Tzu Chin Shan only the syenitic differentiation is represented, but there it has proceeded so far as to produce nepheline-syenites.

Concerning the age relation between the different stems, only in Chiao Ch'eng it has been possible to arrive at a definite conclusion. Here the aegirine-augite-syenites are intruding faults which have certainly dislocated the åkeritic rocks and probably the nordmarkitic as well. The older rocks had solidified and been dislocated, before the aegirine-augite-syenites were intruded. If thus a considerable time-interval must be assumed to exist betwen the åkeritic-nordmarkitic stem on the one hand and the aegirine-augite-syenitic on the other, yet within each stem the differentiation appears to be more continuous. This is clearly illustrated in the P'ing Yang area where the transition from åkerite into nordmarkite and from nordmarkite *via* aplite into quartz-porphyry is characterised by diffuse contacts and numerous transitional types, proving that one rock was not solidified when the next was intruded.

Table 8.

Combined Table of Analyses.

	Group 1 Åkerites				Group 2 a Nordmarkites		Group 2 b Quartz-porphyry	Group 3 Aeg.-aug.-syenites	
	I	V	BrI	BrV	II	K	VI	III	IV
SiO_2	60,78	57,70	62,52	58,48	64,15	62,36	73,48	57,40	60,57
Al_2O_3	15,39	18,77	14,13	19,24	17,90	17,95	14,20	18,57	19,98
Fe_2O_3	4,21	3,62 }	7,38	5,75	2,07	1,55	0,85	2,27	1,76
FeO	1,70	2,88 }			0,74	2,62	0,14	1,33	0,60
MgO	0,95	1,66	1,50	0,99	0,38	0,72	0,14	0,74	0,61
CaO	5,25	5,52	3,36	5,02	2,56	2,75	0,18	3,94	2,44
Na_2O	5,32	4,84	6,25	5,52	6,66	5,60	5,55	6,03	5,04
K_2O	4,56	4,49	3,05	3,06	4,20	4,16	4,79	6,49	6,53
H_2O (+105°)	0,40	0,29	1,20	0,47	0,39	0,87	0,33	0,65	2,32
TiO_2	0,50	0,35	—	—	0,45	0,66	0,05	0,60	0,35
P_2O_5	0,31	0,27	—	—	0,35	0,29	0,10	0,29	0,03
SO_3	—	—	—	—	—	—	—	1,06	0,13
Cl	—	—	—	—	—	—	—	0,12	—
MnO	0,17	0,08	—	—	0,06	0,48	0,01	0,11	0,07
	99,54	100,47	99,39	98,53	99,91	100,01	99,82	99,60	100,43
Moisture	0,26	0,21			0,19			0,18	2,10

Group 1. Åkerites.
I. Åkerite Porphyry. Hu Yeh Shan, Shansi. Analyst: N. SAHLBOM
V. Åkerite Porphyry. Tung T'ai Shan, Shansi. Analyst: N. SAHLBOM.
BrI. Åkerite. Vettakollen, Oslo.
BrV. Quartzbearing Åkerite. Ramnäs, Tönsberg.

Group 2 a. Nordmarkites.
II. Nordmarkite porphyry. Ch'i Huo Ch'i Tung, Shansi. Analyst: N. SAHLBOM.
K. Soda Trachyte. Matsushima, Japan.

Group 2 b. Quartz-Porphyry.
VI. Quartz-Porphyry. Shih Ku Niang Shan, Shansi. Analyst: N. SAHLBOM.

Group 3. Aegirine-Augite-Syenite Porphyries.
III. Nosean-bearing Aeg.-Aug.-Syenite. Hsi Kuang T'a Men, Shansi. Analyst: N SAHLBOM.
IV. Analcitised Aeg.-Aug.-Sy. Porphyry. Liang Chia P'o, Shansi. Analyst: N. SAHLBOM.

The differentiation in a granitic direction is best illustrated in the P'ing Yang area where, as stated above, it has proceeded so far as to produce quartz-porphyry (cf. OSANN's triangular diagram, fig. 50).

The following Table 9 shows the normative mineral composition of the various differentiation products along the granitic stem. In this table the figures for alkali felspars and the sum of femic substances have also been recalculated on the basis of a hypothetical quartz-free rock, these figures appear within brackets.

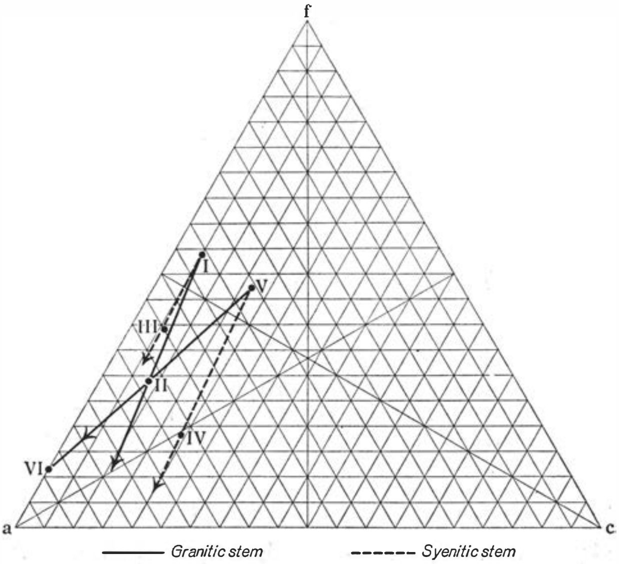

Fig. 50. Diagram (according to OSANN) of the differentiation of the Shansi Alkaline Rocks.
I. Åkerite, Chiao Ch'eng.
II. Nordmarkite, Chiao Ch'eng.
III. Aeg-Aug.-Syenite, Chiao Ch'eng.
IV. Analcitised Aeg.-Aug.-Syenite, Liang Chia P'o.
V. Åkerite, Tung T'ai Shan.
VI. Quartz-Porphyry, Lung Wang Miao.

Table 9.

Normative mineral composition of differentiates along the granitic stem.

Minerals	Åkerite V		Nordmarkite II		Quartz Porphyry VI	
Qu	0		5,10		22,74	
Or	26,69	(67,6)	25,02	(85,0)	28,36	(97,6)
Ab	40,87		56,07		46,01	
An	16,12		6,39		0,00	
	Σ sal 83,68		Σ sal 92,58		Σ sal 97,21	

Di	7,72	Ca SiO$_3$ 1,86	0,00
Hy	2,26	MgSiO$_3$ 1,00	0,40
Acmite	0,00	0,00	0,92
Mt	5,34	1,16	0,23
Ilm	0,61	1,91	0,15
Ap	0,67	0,67	0,34
Hem	0,00	1,28	0,35
	Σ fem 16,60 (16,6•)	Σ fem 6,88 (7,1)	Σ fem 2,32 (3,1)
	H_2O 0,29	0,39	0,33

In the table above nordmarkite II belongs to the Chiao Ch'eng area (being the only one analysed). Åkerite V and quartz-porphyry VI are both from the P'ing Yang area. However, as seen from table 10 below, the P'ing Yang nordmarkite is from a petrographical point of view so very similar to that from Chiao Ch'eng that it may not be inappropriate to use the analysis of nordmarkite II in this connection.

Table 10.

Comparative petrology of nordmarkites from Chiao Ch'eng and P'ing Yang.

Mineral Composition	B_2 Chiao Ch'eng N:o II (Ch'i Huo Ch'i Tung)	C_2 P'ing Yang Sample 425 (Lung Wang Miao)
Quartz	X	X
Alkali felspar	XXX	XXX
Plagioclase	XX ($Ab_{85}An_{15}$)	XX (Oligo.)
Pyroxene	X (Aeg.-Aug.)	X (Diopside)
Amphibole	X	X
Biotite	—	(x)
Sphene	x	x
Ore Grains	x	x
Apatite	—	—

NIGGLI's figures for the Chiao Ch'eng nordmarkite are:

qz	si'	si	al	fm	c	alk	k	mg	ti	p
13	244	257	42	11	11	36	0,30	0,21	1,4	0,5

Corresponding values for NIGGLI's »nordmarkitic-pulaskitic» type magma are

si	al	fm	c	alk	k	mg
250	41	15	5	39	0,35	0,28

To return to the discussion of Table 9 above, the main characteristics of the process of differentiation along the granitic stem are the following:

In the first place a regular increase of salic constituents is noticed (from 83,68 to 97,21 %). Furthermore, the table shows plainly that the

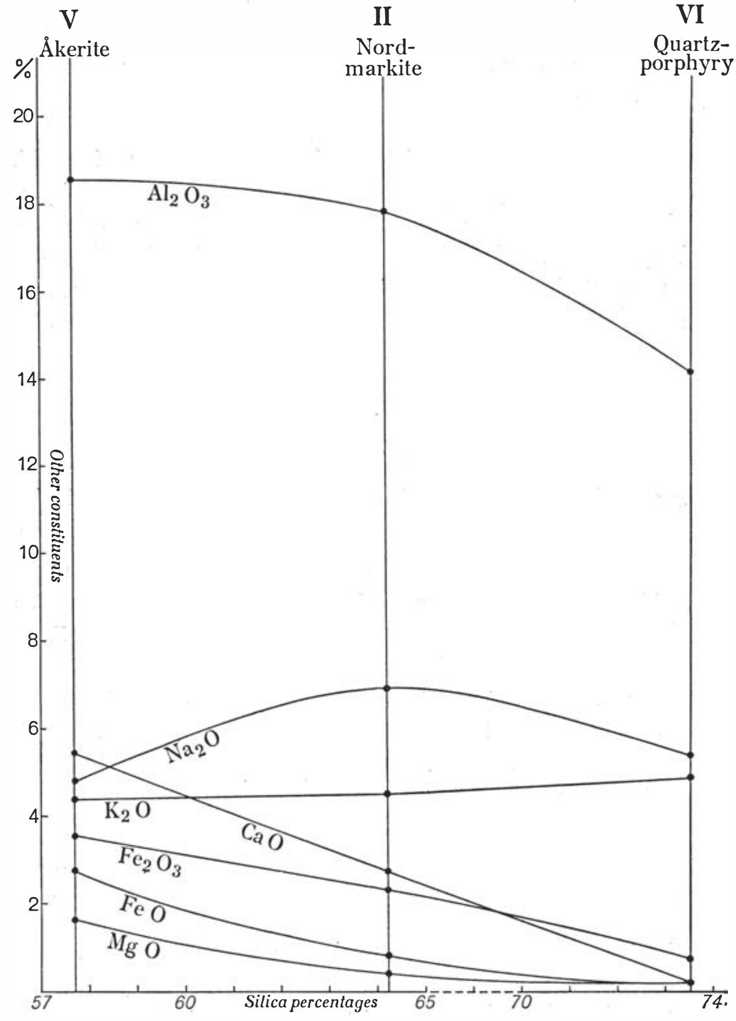

Fig. 51. Percentage diagram (according to HOLMES) showing differentiation of P'ing Yang Rocks.

II. Nordmarkite, Lung Wang Miao (cf. Table 10, p. 143).
V. Åkerite, Tung T'ai Shan.
VI. Quartz-Porphyry, Lung Wang Miao.

mineral constituents may be grouped in two categories, which during the process of differentiation have acted in different manner, viz. quartz and alkali felspar on the one hand and anorthite and femic minerals on the other. To a certain extent this relation is revealed by diagram, fig. 51, where the rocks are arranged (cf. HOLMES 10) according to increasing acidity and in which it is seen that the lime and femic oxides converge to zero, whereas the alkalis are fairly constant.

A clearer conception of the process may be obtained through the following manner of reasoning: the rock may be considered as an ordinary solution of salts in which these are represented by minerals and the solvent is silica. Under this supposition the differentiation has proceeded to a point where the alkaline felspars have been enriched to 97,6 % of the total contents of »salts», whereas anorthite and femic minerals are reduced from 32,72 % to 3,1 %.

As the basic pole of the above described process of differentiation may be considered the banatite-porphyry of Lung Wang Miao (P'ing Yang). It represents the dioritic stem resulting from the splitting-up of the åkerite. The banatite-porphyry constitutes a connecting link between the typical alkali-syenitic rocks of central Shansi and the more plagioclase and quartz-bearing dioritic intrusives of Central China, which are of such economic and universal interest because of their iron-ore-bearing qualities. Lung Wang Miao contains rocks so similar to those of central Shansi as not to be distinguished in hand-specimens, but also highly plagioclase and quartz-bearing varieties reminding one specially of the ore-bearing intrusives of Hung Shan in north Honan (which is situated 250 km to ENE). L. F. YIH in his »Petrography of the dioritic rocks from the contact-metamorphic iron-ore regions af China» (32) describes a granodiorite porphyrite from Hung Shan with phenocrysts of felspar of which the outer zone is formed by untwinned alkali-felspar, while the inner zone polysynthetically twinned. The other constituents also remind one of the banatite-porphyry of Lung Wang Miao. Another fact which emphasizes the transitional nature of the Lung Wang Miao rocks is the higher tenure (as compared with the central Shansi intrusives) of mineralizing agents, producing abundant contact minerals just as on Hung Shan, namely epidote, garnet and iron-ore (hematite), thus placing Lung Wang Miao in a position more approaching the ore-bearing intrusives of central China.

At a time, considerably later than the eruption of the granitic and dioritic magmas above described, the intrusions of the highly alkaline magmas took place. The oldest rocks of this stem are in all three areas varieties of aegirine-augite-syenites, the composition of which is shown below.

Table 11.

Composition of aegirine-augite-syenites from Shansi.

Group 3.

Mineral Composition	A_3 Chiao Ch'eng III Hsi Kuang T'a Men	B_3 P'ing Yang IV Liang Chia P'o	C_3 Tzu Chin Shan
Quartz	—	—	—
Alkali felspar	XXX (Sodic ortho.)	XXX (Sodic ortho.)	XXX (Sodic ortho.)
Plagioclase	X (Albite)	XX (Albite-oligo.)	?
Nepheline	—	—	X
Pyroxene	X (Aeg.-augite)	X (Aeg.-augite)	X (Aeg.-augite)
Amphibole	—	—	x (Alkali amph.)
Sodalite min.	xx (Nosean & Sodal.)	—	x (Sodalite)
Analcite (secondary)	—	XX	—
Melanite	X	—	—
Sphene	x	x	x
Ore Grains	x	x	x
Apatite	x	x	x
Structure	Hyp-Abyssic	Hyp-Abyssic	Abyssic

This group is characterised by high tenure of alkali (11 to 12,5 %) and low tenure of lime (2,5 to 4 %), K_2O and Na_2O are present in approximately equal quantities with a tendency of the former to predominate. In NIGGLI's system the rocks A_3 and B_3 will show the following position:

	qz	si'	si	al	fm	c	alk	k	mg	ti	p
A_3	—40	237	197	37,5	13,8	14,4	34,3	0,42	0,28	1,6	0,4
B_3	— 6	238	232	45	10,6	10	34,4	0,46	0,33	0,9	—

NIGGLI's »leukosyenitic» magma type

178	40	14	11	35	0,55	0,30

The following Table 12 shows the normative mineral composition of the various differentiates along the syenitic stem:

Table 12.

Normative composition of rocks along the syenitic stem.

Minerals	Akerite V	Aeg.-Aug.-Syenite IV	Nosean-Aeg.-Aug.-Sy. III
Qu	0	0,42	0
Or	26,69	38,36	38,36
Ab	40,87	42,44	36,16

An	16,12	12,23	8,34
C	0	0,20	0
Neph	0	0	3,98
Na_2SO_4	0	0	1,85
2 NaCl	0	0	0,12
	Σ sal 83,68	Σ sal 93,65	Σ sal 88,81
Di	7,72	0	0
$CaSiO_3$	0	0	3,83
$MgSiO_3$	0	1,50	0
Mg_2SiO_4	0	0	1,26
Hy	2,26	0	0
Mt	5,34	0,93	2,78
Hem	0	1,12	0,32
Ilm	0,61	0,61	1,22
Ap	0,67	0	0,67
Pyr	0	0,12	0
	Σ fem 16,60	Σ fem 4,28	Σ fem 10,08
	H_2O 0,29	2,32	0,65

Apart from the abnormalcy pertaining to No. IV on account of hydrothermal analcitisation, the analyses exhibit certain characteristic features. In the first place the distinct and gradual diminution of anorthite and femic minerals with increasing alkalinity is very evident. Furthermore, the tenure of potassium is increasing in the same direction, whereas sodium shows a slight tendency to decrease. The most extreme alkaline differentiate shows considerable tenure of normative nepheline.

The differentiation in the direction åkerite → aegirine-augite-syenite is illustrated in OSANN's triangular diagram (cf. p. 142). It proceeds towards the line a—c parallel to side a—f (I—III Chiao Ch'eng, V—IV P'ing Yang).

Still more instructive is the percentage diagram, fig. 52 according to HOLMES (10). It shows the chemical composition of the parent rock I of Chiao Ch'eng and the principal products of differentiation in a granitic (II) and syenitic (III) direction. In both cases the process has been virtually similar and consisted in an enrichment of aluminium and alkalis and impoverishment of anorthite and femic oxides. The proportions between the metallic oxides is nearly constant and the main difference lies in the amount of silica present. Compared with the granitic derivative the alkali syenite may be considered as a more concentrated silica solution of the metallic oxides of the åkeritic parent magma. There is no indication whatsoever that the proportion between the metallic oxides has undergone any considerable change by absorption of extraneous matter, e. g. limestone.

Whereas in the Chiao Ch'eng and P'ing Yang districts we do not find any differentiation in syenitic direction more far-reaching than to produce aegirine-augite syenite, at Tzu Chin Shan the process has gone

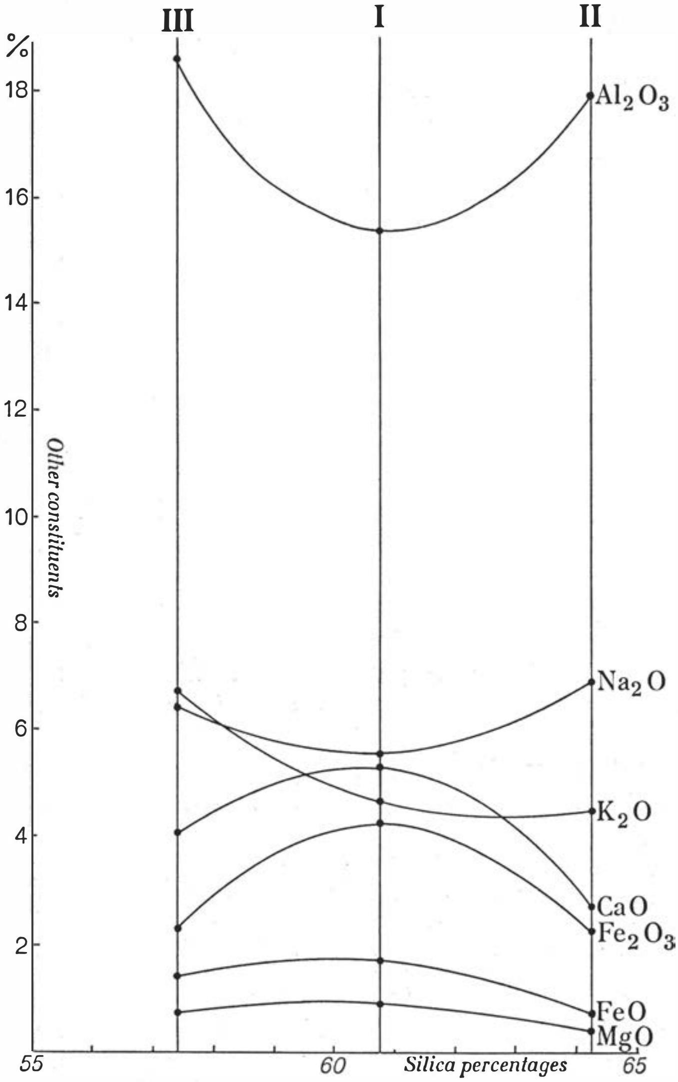

Fig. 52. Percentage diagram (according to HOLMES) of the Chiao Ch'eng rocks.
I. Åkerite of Hu Yeh Shan.
II. Nordmarkite of Ch'i Huo Ch'i Tung.
III. Aeg.-aug.-syenite from Hsi Kuang T'a Men.

so far as to evolve nepheline-bearing and leucite-bearing rocks. In this area it has been shown that more and more alkaline magmas have been intruded with short time-intervals, a magma-tectonic process which is also in evidence when observing the differentiation along the granitic stem of Lung Wang Miao (P'ing Yang).

According to the literature available, two regions exist where the consanguineous features ressemble those met with in Shansi: one is the Christiania (Oslo) field, the other is situated near Hobart in southern Tasmania. In the former area (cf. BRØGGER 4 and 5) the oldest intrusions are essexitic and laurdalitic magmas, the latter including nepheline-bearing varieties. Then come åkerite and related rocks, with which, *via* a series of rocks of increasing acidity, are connected sodic granites and quartz-porphyries. The series is: åkerite—nordmarkite—sodic granite— granitite—quartz-porphyry. Between the first three the age relation is in the order as above. This fully coincides with the differentiation along the granitic stem as known from P'ing Yang and Chiao Ch'eng. — On the other hand, near Hobart, Tasmania, an area is known (cf. PAUL 21)[1] in which with essexites are associated: åkerites, aegirine-augite-syenites, melanite-hauynite-syenite-porphyry and nepheline-syenites. Some of these rocks show also microscopically very great similarity to the Shansi rocks. The coincidence with the Tzu Chin Shan rocks is striking.

VI. Age of the Shansi Alkaline Intrusives.

Although in Chiao Ch'eng and P'ing Yang no intruded sediments younger than the Permian are observable in the field and at Tzu Chin Shan the corresponding horizon is probably not later than Mid-Mesozoic, and thus the upper time limit of intrusion is impossible to define on purely stratigraphical grounds, yet the evident connection of magmatic action with the formation of the major faultlines of Shansi will reduce the problem to the answering of the question: at what period did these great dislocations take place?

The important epochs of Post-Palaeozoic diastrophism in north China are (cf. ANDERSSON 2):

1. in Jurassic time — folding; porphyritic intrusions; dioritic laccoliths;
2. { » Oligocene time — folding in Kansu, Shantung, Fengtien; basaltic eruptions;
   { » Miocene time — blockfaultings.

The former cannot have been the cause of the great faults in Shansi as it has been observed (cf. ANDERSSON 1) that sediments as young as Eocene have been affected by these tectonic movements.

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[1] The original report by W. H. TWELVETREES and W. F. PETTERD (25) has not been available to the writer.

Some recent opinions on this subject have been summarized by Dr W. H. WONG in his »Structures seismogéniques en Chine» (29) in the following words: »Tous les accidents seismogéniques ci-dessus décrits sont certainement post-mésozoiques, puisque toutes les formations de cette periode en sont affectées. J. G. ANDERSSON a récemment decouvert à Yuentchu (Yuan Chü) au sud de Chansi un dépôt consolidé éocène également disloqué, ce qui semble indiquer que les derniers mouvements tectoniques en Chine doivent au-moins être post-éocènes.

Les considérations physiographiques ont conduit BAILEY WILLIS à attribuer les failles et les flexures du Chantoung à l'éocène et celles du Chansi à un âge plus recent. L'auteur américain pensait en effet que son étage physiographique de Fen-Ho, c'est à dire l'époque du dernier mouvement tectonique, est postérieur au loess. — — — Des formations de talus au pied des lèvres soulevées de failles analogues au conglomérat de Wen-Ho et au gravier de Ning-Chan décrits par WILLIS et BLACKWELDER ont été rencontrées en abondance le long de Tai-Hang-Chan et les failles limitrophes du fosse Wei-Ho—Fen-Ho. Ces conglomérats ou graviers s'interstratifient quelquefois avec des couches de terre rouge. M. ANDERSSON croit pouvoir identifier ces formations avec son gravier de Ma-Lan lequel est synchronisé avec la terre rouge à Hipparion de l'âge pliocène.»

There seems thus to be complete agreement that the tectonic movements in question are Post-Eocene, but regarding further definition evidence seems still to be insufficient.

It is possible that most of the intrusions date from the closing stages of maximum diastrophism during Oligocene or Mid-Tertiary, as in the writer's opinion they cannot be of excessively recent origin. The intrusions have, with exception of those at Tzu Chin Shan, taken place at comparatively great depths and it will have required long time to remove the sedimentary cover so far as to expose the intrusives. Moreover, this removal had to be accomplished in Pre-Pliocene time as can be seen by the occurrence of »Hipparion» red clay on the igneous exposures at Lung Wang Miao (cf. p. 110). Consequently, if the age of the Shansi alkaline intrusives is defined to middle Tertiary the assumption is probably on the safe side. More field evidence is necessary to obtain a further narrowing down of the time-limits.

VII. Other Occurrences of Alkaline Rocks in the Far East.

During the last decades attention has been more and more directed towards the existence of alkaline rocks in the Far East. Thus highly alkaline rocks have been found at several places associated with basaltic magmas in Manchuria, in Korea, on islands in the Sea of Japan and in

Shantung, all of supposed Tertiary age. Beside these occurrences alkali-syenites are now known to exist in the Ordos and in Szuchüan and alkali granites in Fukien. The age of the latter intrusives is not known.

The Ordos rock found as boulders by Pères E. LICENT and P. TEILHARD DE CHARDIN was decribed by LACROIX and named by him *ordosite* (cf. LACROIX 14). The locality is in NW Ordos, 400 km WNW of Tzu Chin Shan. In the desert opposite the mission San-Tao-Ho, on the right bank of the Yellow River, two kinds of boulders were found, one a tinguaite rich in felspar phenocrysts, and one consisting exclusively of microcline, phlogopite and aegirine. The new rock has large grey-violet felspar phenocrysts in a grass-green groundmass. It contains nearly 60 % aegirine and occupies, according to LACROIX, the central position in a series, of which one extreme is poor in silica and is occupied by the nepheline-bearing lujavrite and the other end rich in silica and occupied by the quartz-bearing fastibitikite.

Although the distance from Shansi is considerable, yet it is interesting that exploration just commenced of the little-known Ordos has disclosed petrographic discoveries in this line. LACROIX (op. cit.) believes, owing to abundance of blocks and uniformity of substance, that the ordosite may occupy large homogenous masses, but does not deny the possibility that it may be a *facies* of a less exceptional syenite. This would bring it more in line with the Shansi rocks.

In Huei-Li district in southern Szuchüan province, west China, two nepheline-syenite intrusives are known and mentioned by W. H. WONG (30). A nepheline basalt from Yang Shan, west of the town Wei Hsien in Shantung has been described by A. LANICK (15). It is an amygdaloid rock in which nepheline is present not in the form of crystals but as leptomorphic mesostasis.

Information regarding alkaline rocks in Japan, Chosen (Korea) and Manchuria has been put at the writer's disposal through the kindness of Dr B. KOTO, Emer. Prof. of Geology, Tokyo Imperial University. KOTO himself noticed several years ago alkaline rocks at the eastern end of Hokkaido, intruding Cretaceous. Also in the Shiretoko peninsula of Japanese Sakhalin, intruding Tertiary. Later on specimens were sent to KOTO from Tendai-san in the islet of Hattaku-to in the Pescadores and from Reisuiko near Taihoku, Formosa. They seem to be analcite-basalt. S. KOZU of the Imper. Geol. Survey of Japan has described an aegirine-trachyte from the islets of Matsushima and Kakara-Jima, 6 $^1/_2$ km NW of Yobuko, prov. Hizen (13). This rock, called by KOZU soda-trachyte, shows in its chemical composition (cf. combined table of analyses p. 141) strong similarity to some of the Shansi rocks. Its mineral composition is: lime-bearing anorthoclase, sometimes with nucleus of plagioclase, or perthitic; aegirine-augite, magnetite, apatite. Groundmass: trachytoidally arranged alkali-felspar prisms. Quantitative System: *Laurvikose*, near *Pulaskose*. It thus agrees also mineralogically with the corresponding

Shansi rocks. It contains however, though sparsely, olivine which has not been found in our rocks. Its association is interesting inasmuch that we have according to KOZU the following series:

Olivine-basalt—alkali-felspar-bearing basaltic rocks—soda-trachyte.

KOZU mentions also alkali-felspar-bearing basalt from the N part of Kyushima, one of the Idzu islands and from the islands Koto-sho (Botel Tobago), Taiwan.

Lately F. YAMANARI has added to our knowledge of the Japanese alkaline rocks by his paper (31). YAMANARI mentions the presencc of

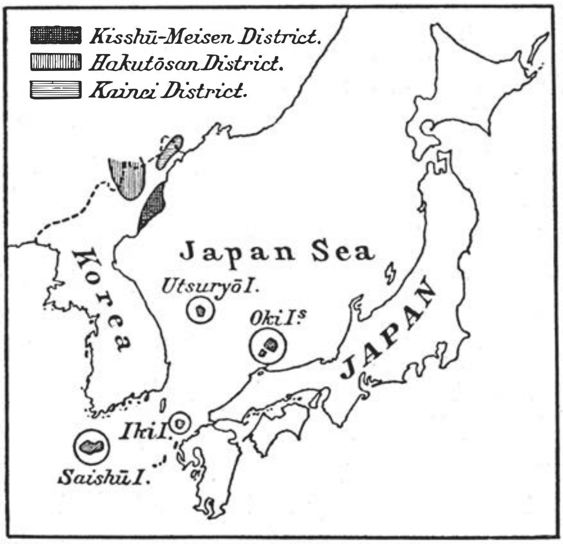

Fig. 53. Map of localities of Alkaline Rocks in or at the Sea of Japan (repr. from F. YAMANARI: Soda-pyroxenes in the tertiary and post-tertiary Alkaline Rocks from the environs of the Sea of Japan).

alkaline rocks (alkali trachyte, phonolite and leucitic rocks) on Utsuryo, Oki, Iki and Saishu islands situated in the SW part of the Sea of Japan (see fig. 53) YAMANARI'S conclusions will be further stated below. The leucite rock from Utsuryo has been decribed in detail by SEITARO TSUBOI (24). It contains nearly equal amounts of alkali and lime-soda-felspars with a little leucite in the groundmass, also brown hornblende, aegirine-augite, titan-augite, accessory biotite, olivine, apatite and magnetite. Its analysis reminds one of the composition of some of the Shansi rocks and its position in the CIPW system is *monzonose-pulaskose* (cf. p. 119 and 126): S. TSUBOI considers the history of the island to be:

Period of basalts—erosion—period of trachytic rocks—depression of the apical part of the trachytic body—period of the leucite rock.

Regarding alkaline rocks in Chosen (Korea) and Manchuria such have been found principally at or near the eastern part of the frontier between these two countries, viz. in Kisshu-Meisen, Hakutosan and Kainei districts (see map). T. ICHIMURA (11) states that he collected specimens of alkali-syenite on the pass of Kandoho, about 7 miles west of Kainei, and mentions that many new localities of such rocks were found in the Tertiary area of the frontier region. In all cases the alkaline-syenite was not only detected in close association with dolerites, but occurs only within laccoliths or dykes of the same rock. Such dykes are well developed at Kandoho, Chutoko, Endaiho, Shochodosokusan and Genzando, whereas large bodies occur in the vicinity of Endaiho. The alkali-syenite here is a rock of light grey colour and consists of orthoclase, augite, aegirine-augite, aegirine and analcite. Plagioclase and titan-augite are rare, but alkalic amphiboles have been found here and there. Aegirine-rimmed augite seems typical, also presence of analcite. ICHIMURA believes from sundry geological evidences that the period of intrusion is at least later than the deposition of the Tertiary beds (Miocene or thereabout) and older than the enormous faulting to which the present course of the river To-manko (Tumen) owes its existence.

In Manchuria B. KOTO found nepheline-basalt at Yingé Mên (cf. 12).

To quote further F. YAMANARI (op. cit.): While more acidic or sodic alkaline rocks which bear soda-pyroxene and amphibole are present in large quantity along the N coast of the Japan Sea, soda-trachyte which contains always trachy-augite as the only coloured constituent, is abundant on Utsuryo, Oki and Saishu islands in the SW part of the Japan Sea. In other words the Tertiary alkaline magmas in the circum-Japan-Sea region were more alkalic ($Al_2O_3 < K_2O + Na_2O$) towards the N coast and more sub-alkalic ($Al_2O_3 > K_2O + Na_2O$) towards the southern. Consequently both Hakutosan and Kisshu-Meisen districts are rich in alkaline rocks and Utsuryo, Oki and Saishu islands exhibit mainly subalkaline rocks, though alkaline rocks exist in small amounts. Coming further south, Japan proper is characterised entirely by lavas of calc-alkalic types, except a few rare occurrences of alkaline rocks.

Summary.

In recent years numerous areas of highly alkaline rocks have been discovered in Shansi by the Geological Survey of China and the Nyström Institute. It is rather remarkable that in other parts of the great republic 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 central part of this province is an area mostly covered with palaeozoic and younger sediments and enclosed towards north and south by two broad and strongly folded mountainous zones, viz. the Mongolian border-range in the north (or the extension of Great Ch'ing-An) and the Tsing-Ling fold-system in the south. 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 running NNE—SSW and in the south parallel to folds running ENE—WSW.

The known areas of Shansi alkaline syenites are all situated within the central zone, but near or within the regions where the different systems of trendlines meet.

At present there are known three areas of alkaline rocks in Shansi, namely the following:

1) The central Chiao Ch'eng (Hu Yeh Shan) intrusives about 65 km west of the capital Taiyuanfu;

2) The P'ing Yang intrusives 20—50 km ESE and SE of P'ing Yang Fu in south Shansi;

3) Tzu Chin Shan, 160 km WNW of Taiyuanfu.

In the first-named area the sequence of events has been the following: The oldest intrusion has taken place in the shape of a comparatively large laccolith intruded in the Ordovician limestone just below its surface (which is overlaid by Carboniferous). The igneous body consists of åkerite. Apart from certain structural variations towards the margin of the body, the rock exhibits a fairly constant appearance within the entire laccolith. In hand-specimens it is a rock of medium grain and pink or whitish colour and is sprinkled with small crystals of bisilicates. The microscopical and chemical analysis classifies the rock as an alkali-syenite, which may be called åkerite inclining towards monzonite. The characteristic feature of its mineral composition is the combination orthoclase, often microperthitic, and plagioclase ranging from andesine to oligoclase-albite. The dark minerals appear in various proportions of diopside and common hornblende. Sphene is rather abundant, more subordinate are quartz, magnetite and zircon.

Closely connected in the field with these åkerites and genetically to be considered as more acid differentiates from them, are the nordmarkitic rocks which form the massif Ch'i Huo Ch'i Tung north of the main body. It is highly probable that these rocks have been intruded simultaneously with or slightly posterior to the main Hu Yeh Shan laccolith. In hand-specimens they are rather similar to the åkerites, but differ from these by greater tenure of quartz which is often macroscopically visible. Chemically the nordmarkite shows higher acidity and alkalinity than the parent rock and this is revealed by appearance of more acid plagioclase and of aegirine-augite.

At a time posterior to the consolidation of the above-mentioned intrusives, important tectonic movements took place, by which the northern rim of the Hu Yeh Shan laccolith and the territory to the north of it were broken up in blocks and tilted. These dislocations were followed by renewed igneous activity. Thus in the north-west part of the territory channels were opened up through which the magma penetrated to higher levels. It is possible that certain remants of a hypothetical laccolith which are found on top of Hu Yeh Shan und which show mineral composition similar to the north-western rock may have a common origin with these.

These younger intrusives are of medium grain and grey colour and are all distinguished by higher alkalinity than those mentioned above. They may be classified as aegirine-augite-syenites and of these several varieties are found which are characterised by presence of the accessories melanite, nosean and sodalite, which occur in different quantity. These aegirine-augite syenites are also distinguished from the older rocks by the almost complete absence of soda-lime-felspar. Chemical examination justifies its position as a highly alkaline syenitic rock because of high tenure of K_2O and Na_2O, very low silica and the presence of considerable amounts of primary SO_3 and Cl.

Another characteristic feature of these highly alkaline bodies in contrast to the older laccolithic intrusives is the abundance of dykes which penetrate the main stocks and the surrounding sediments. Their mineral composition is similar to the main rock and they differ only by more porphyritic development.

Turning our attention to the southern intrusives it is seen that the main body—Lung Wang Miao—exhibits certain magma-tectonic features different to those in the Chiao Ch'eng area. Whereas in the latter region the åkerites have penetrated into a comparatively undisturbed sedimentary series, the Lung Wang Miao magma has intruded a pre-existing anticline which has been, in connection with the intrusion, somewhat deformed. Also here the magma has intruded the upper part of the Ordovician limestone.

The oldest and principal rock of the Lung Wang Miao igneous body is an åkerite which shows remarkable similarity to the åkerites of Chiao Ch'eng. The only difference is a slightly higher tenure in the former of lime-soda-felspar. — From this åkerite have originated series of derivatives; one in a granitic direction proceeding through nordmarkite and producing quartz-porphyry as final product, one in a dioritic direction forming banatites. The intrusion of these differentiates has occurred with no considerable time-intervals.

The Lung Wang Miao nordmarkite, though on the whole very similar to the corresponding rock from Chiao Ch'eng, differs somewhat in the sense of lower alkalinity which is seen mainly by the fact that the pyroxene in the former is free from aegirine and occurs as diopside.

A noteworthy feature of the evolution of the Lung Wang Miao rocks is the occurrence of granite aplite, acid porphyries and banatites which are unique in the alkaline areas of Shansi. In its most typical development the quartz-porphyry is a light pink rock, in the dense groundmass of which are found well-developed crystals of felspar and bi-pyramidal quartz. It lacks femic minerals except a few ore-grains. The microscope shows the felspar phenocrysts to be perthitic potash-felspar and the groundmass to consist of quartz, alkali-felspar, a little plagioclase and a few ore-grains. High tenure of alkalis and free quartz and exceedingly low percentage of lime and femic oxides are the characteristic features of this rock.

The banatite porphyry which represents the basic pole in the splitting-up of the åkerite magma, is a light grey or pinkish white, porphyritic rock consisting of oligoclase and subordinately-potash-felspar, quartz, common hornblende and accessories. It shows certain affinity to the ore-bearing diorites of central and northern China.

In the same manner as in Chiao Ch'eng also in the P'ing Yang district more alkaline intrusives are found in the shape of necks or stocks. Those known at the present time are: Tung T'ai Shan, Shih Tsun Shan and Liang Chia P'o.

Broadly speaking, the differentiation in alkali-syenitic direction exhibited in these satellitic bodies has not proceeded as far as in Chiao Ch'eng. Generally the increasing alkalinity is only manifested by the appearance of aegirine-bearing augite and preponderance of potash felspar. The most alkaline type is to be found at Liang Chia P'o where the intrusive rock appears as a highly analcitised aegirine-augite-syenite-porphyry. Chemically it occupies an intermediate position between the åkerite and the nosean-aegirine-syenite of Chiao Ch'eng. The most noteworthy feature of this intrusive is the strong analcitisation the rock has undergone during the later stage of volcanic action.

While thus in the P'ing Yang area the differentiation has proceeded rather far in a granitic and dioritic direction, the evolution in a syenitic direction has come to a standstill at an early stage. In the eruptive formations of Tzu Chin Shan in west Shansi the diagram of evolution is amplified in a beautiful manner by a very complete series of syenitic differentiates. Here extremely alkaline syenitic derivatives have originated from an åkeritic parent-magma. The principal stages of this evolution are marked by the following series:

åkerite—aegirine-augite-syenite (sometimes sodalite-bearing)—nepheline-syenite and leucite-syenite.

A prominent feature of Tzu Chin Shan is the presence of a volcanic neck which, judging from its porous nature, should represent a section near the ancient land-surface.

In all the investigated areas the different main magma injections have been found to appear not in a haphazard manner but to prefer certain horizons of the sedimentary cover of the areas in question, and then generally in such manner that the higher up in the sedimentary series they are intruded, the greater is the alkalinity of the igneous rocks. Thus it has been found that the main åkerite-laccoliths appear in all cases just below the top of the Ordovician limestone. In this same horizon laccolithic intrusions of more alkaline rocks are never found, but only channels in the form of stocks, necks or dykes. The laccolithic intrusions connected with these channels are invariably found at higher levels of the sedimentary series. Furthermore, it does not seem accidental that Tzu Chin Shan which represents an intrusions within the highest layers of the sedimentary cover (probably Mesozoic), near the old land-surface, also exhibits the rocks of most extreme alkalinity.

Concerning the association of rocks within each of these areas it seems that the extreme differentiates converge through transitional types towards a parent rock of åkeritic composition, very similar in all three districts. Based on the sequence of eruption and the petrographical composition the process of differentiation may be considered to have followed three different directions: the granitic, syenitic and dioritic stems, cf. diagram fig. 49. In the P'ing Yang territory all three stems are represented, in Chiao Ch'eng only the granitic and syenitic and in Tzu Chin Shan only the syenitic. Although thus the final products are not identical, yet there is small doubt that in all cases the process of differentiation has been essentially the same. The splitting-up of the parent magma in a granitic and dioritic derivative seems to have taken place simultaneosly. By elimination of the granitic differentiate the parent magma has lost a considerable amount of its silica contents, and in the same manner, by elimination of the dioritic differentiate, there has been impoverishment in plagioclase and femic minerals. From the residual magma the more alkaline syenitic differentiates have originated.

A study of the available literature has shown that similar evolution has taken place also in åkeritic areas in other parts of the world. It is however seldom that the various series of differentiates have been exposed and their mutual relations revealed to such an extent as in the various localities in Shansi. In the Christiania (Oslo) field described by BRØGGER, there exists a very complete series of differentiates from åkerites through nordmarkite, sodic granite, granitite to quartz porphyry, which closely agrees with the granitic differentiation at Lung Wang Miao. — Also near Hobart, Tasmania, an area is known where with åkerites are associated on the one hand a series of essexites and on the other hand aegirine-augite-syenites, melanite-hauynite-syenite-porphyry and nepheline-syenites, corresponding to the alkali-syenitic differentiation in Shansi.

Regarding the age of the Shansi alkaline rocks it has not been possible to arrive at any definite conclusions on account of absence in the areas concerned of dateable sediments contemporaneous with or younger than the intrusions. With regard to Tzu Chin Shan however it is possible to say that they are younger than Mid-Mesozoic. In the case of the Chiao Ch'eng and P'ing Yang areas the intrusions are in such striking manner connected with the formation of the Mo Erh Tung and Ho Shan horsts, that the conclusion lies near at hand that both have taken place more or less simultaneously.

The periods of major Post-Palaeozoic diastrophism in north China are the Mid-Mesozoic and Oligocene-Miocene. Since in Shansi Eocene strata have been afflicted by the fault-movements mentioned above, the former period must be ruled out, when the age of the intrusives is considered. It is quite possible that the dislocations in question occurred during Oligocene and that the intrusions took place during the closing stage of these tectonic movements. That some of the major dislocations took place before the Pliocene is made probable by the occurrence ot Basal Pliocene »Hipparion» clays interstratified with the gravels at the foot of the faulted blocks. It is thus believed that the age of the Shansi alkaline intrusives may be given approximately as Mid-Tertiary.

Addendum.

During the printing of this paper the following analyses of Shansi rocks have come to hand, as quoted in the report: »Rocks of Eastern China» by H. S. WASHINGTON and MARY G. KEYES of the Geophysical Laboratory, Carnegie Institution of Washington (repr. from the Journal of the Washington Academy of Sciences, Vol. XVI, N:o 11, June 4, 1926).

	(1)	(2)	(3)
SiO_2	55,38	56,40	53,75
Al_2O_3	15,47	19,74	18,71
Fe_2O_3	3,77	2,15	4,60
FeO	3,46	1,04	0,56
MgO	2,20	0,21	0,03
CaO	6,65	2,93	1,11
Na_2O	4,77	2,75	5,43
K_2O	5,11	12,42	12,64
H_2O+	0,36	0,33	0,78
H_2O-	0,03	0,28	0,07
TiO_2	1,96	1,52	1,61
P_2O_5	0,36	0,14	none
SO_3	n. d.	n. d.	0,25
Cl	n. d.	n. d.	0,14
MnO	0,11	0,08	0,13
BaO	n. d.	n. d.	0,01
	99,63	99,99	99,82[1]

(1) Augite-syenite, II. 5. (1) 2. 3''. Tzu Chin Shan, Lin Hsien, Shansi. KEYES anal.
(2) Nepheline-syente, I (II). 6. 1''. 2 » » » » » » »
(3) Pseudoleucite-tinguaite, II. 7. 1. 2 » » » » » » »

[1] Includes ZrO_2 none, Cr_2O_3 none.

Comparison is invited between analysis (1) and that of the åkerite porphyry from Tung T'ai Shan, S. Shansi, (cf. p. 119). Analyses (2) and (3) above show remarkably high contents of alkalies, especially potash. The subrang, I. 6. 1. 2 in which rock (2) falls, is as yet unrepresented by any analysis so that this subrang may be named *shansose*.[1] The Shansi pseudoleucite-tinguaite ressembles closely, modally and texturally, the corresponding rock of Bear Paw Mountains, Montana, and of Beemerville, New Jersey.[1]

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[1] Quotations from above-mentioned paper: Rocks of Eastern China.

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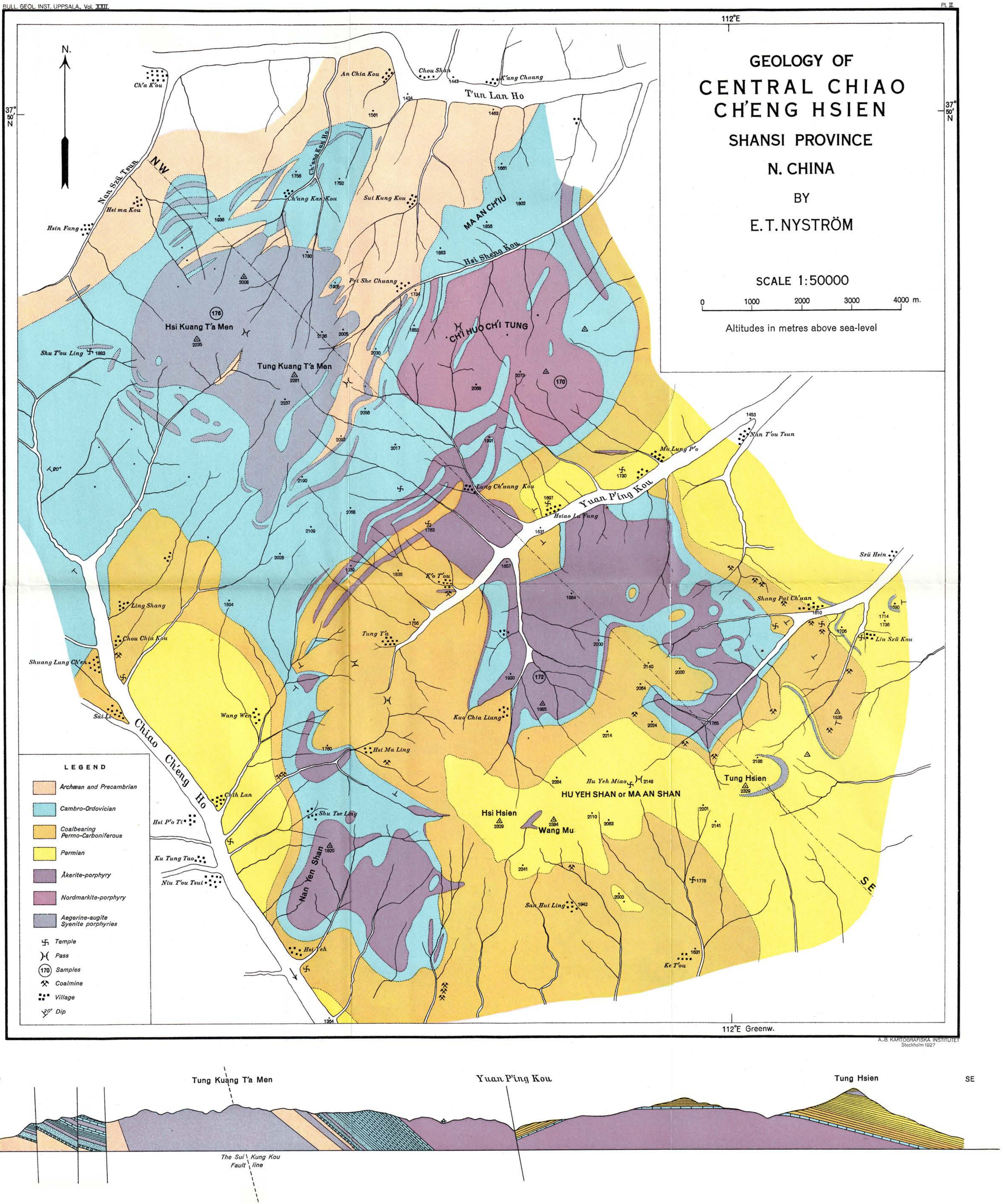
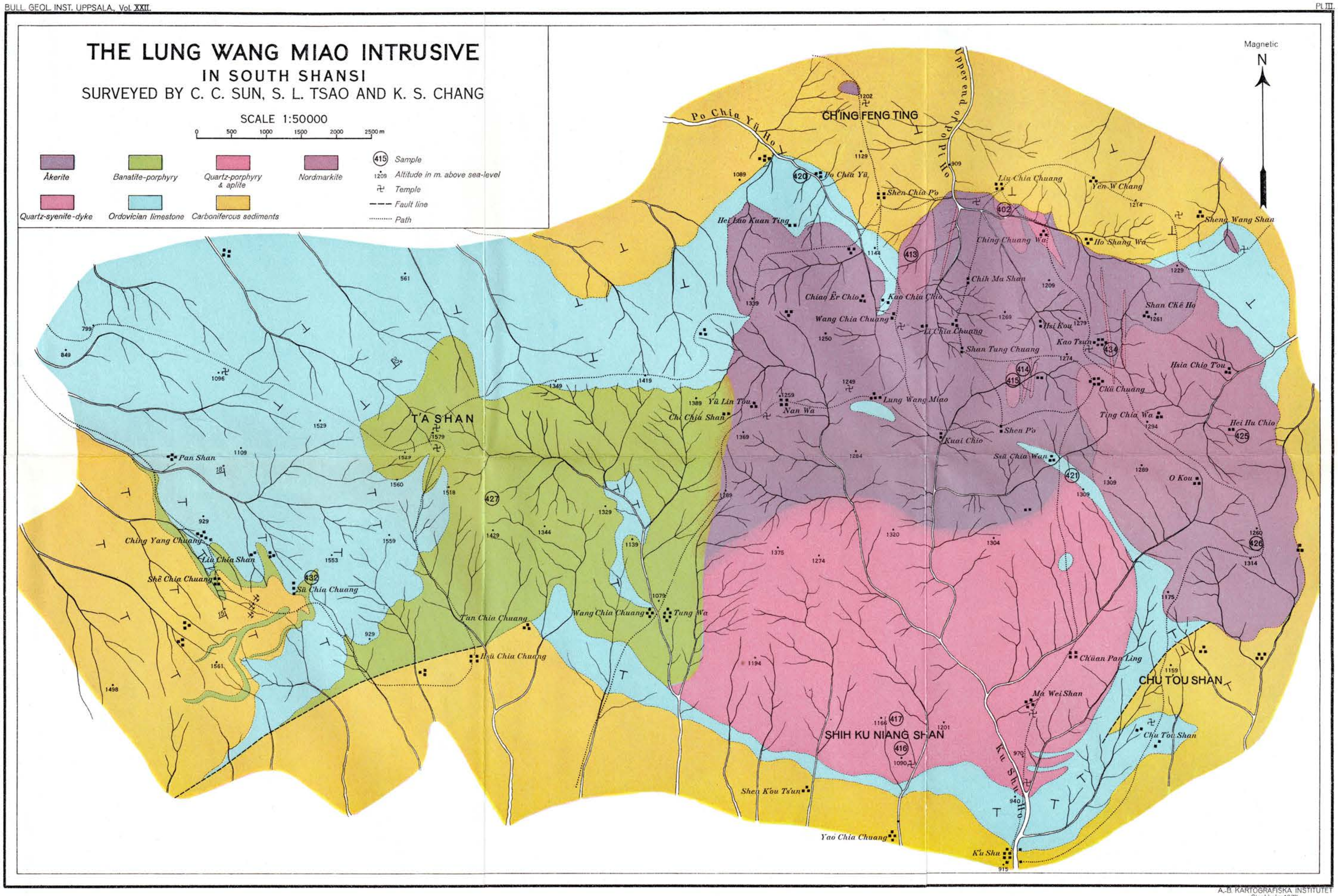
Corrigenda.

P. 101 line 3 from above read SSE instead for SE.

» 104 » 4 » below » »specimens of *Alethopteris* closely related to Permian forms» instead for »*Alethopteris Armasi* and *A. plebeia,* both well-known Permo-Carboniferous plants».

Gedruckt 3/9 1927.


GEOLOGY OF
CENTRAL CHIAO CH'ENG HSIEN
SHANSI PROVINCE
N. CHINA
BY
E. T. NYSTRÖM
SCALE 1:50000
0 1000 2000 3000 4000 m.
Altitudes in metres above sea-level
112°E
37° 50' N
N.
LEGEND
Archæan and Precambrian
Cambro-Ordovician
Coalbearing Permo-Carboniferous
Permian
Åkerite-porphyry
Nordmarkite-porphyry
Aegerine-augite Syenite porphyries
Temple
Pass
Samples
Coalmine
Village
20° Dip
T'un Lan Ho
An Chia Kou
Chou Shan
K'ang Chuang
Ch'a K'ou
Nan Szŭ Tsun
Hsi ma Kou
Hsin Fang
Ch'ang Kan Kou
Sui Kung Kou
MA AN CH'IU
Hsi Sheng Kou
Pei She Chuang
Hsi Kuang T'a Men
Tung Kuang T'a Men
CH'I HUO CH'I TUNG
Shu T'ou Ling
Nan T'ou Tsun
Mu Lung P'o
Lung Ch'uang Kou
Hsiao Lu Fang
Yuan P'ing Kou
K'o T'ou
Szŭ Hsin
Shang Pai Ch'uan
Liu Szŭ Kou
Ling Shang
Chou Chia Kou
Shuang Lung Ch'en
Tung T'a
Sai Li
Wang Wen
Kuo Chia Liang
Hsi Ma Ling
Chiao Ch'eng Ho
Chih Lan
Hsi P'o Ti
Shu Tse Ling
Ku Tung Tao
Niu T'ou Tsui
Nan Yen Shan
Hu Yeh Miao
HU YEH SHAN or MA AN SHAN
Tung Hsien
Hsi Hsien
Wang Mu
San Hui Ling
Ke T'ou
Hsi Yeh
NW
SE
112°E Greenw.
A.-B. KARTOGRAFISKA INSTITUTET Stockholm 1927
NW
Tung Kuang T'a Men
Yuan P'ing Kou
Tung Hsien
SE
The Sui Kung Kou Fault line



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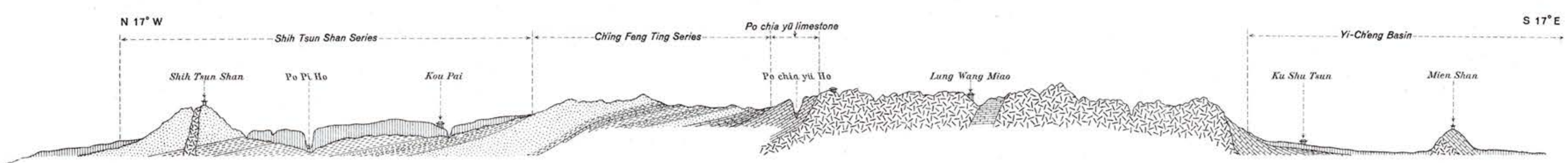
Stockholm 1927

SECTION A

THROUGH MIEN SHAN, SHIH KU NIANG SHAN, LUNG WANG MIAO, CH'ING FENG TING AND SHIH TSUN SHAN

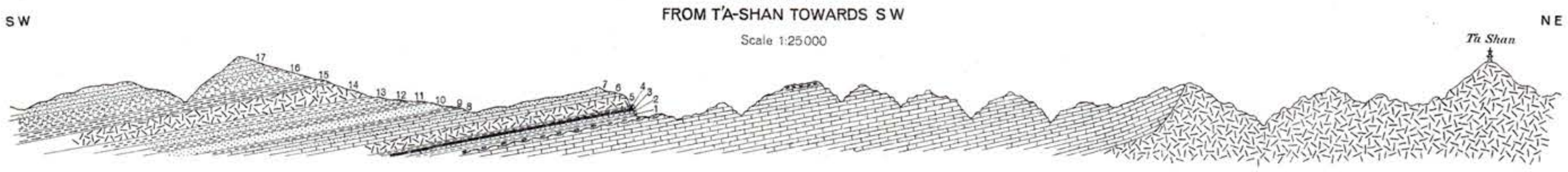
Scale 1:100000



SECTION B

FROM T'A-SHAN TOWARDS S W

Scale 1:25000



Sandstone Limestone & marble Shale & marl Loess Igneous rocks Coal seam