

of the sequence as rhyolite and dacite with amygdaloidal, flowage and porphyritic structures and microcrystalline, aphanitic and micro-eutectic textures. Main mineral content, plagioclase 30—45%, K-feldspar 20—31%, quartz 10—15%, and some hornblende, biotite and pyroxene. Rhyolite shows flowage and amygdaloidal structures or porphyritic, with microcrystalline globular, micro-eutectic and aphanitic textures in the matrix. Mineral content is similar to those of dacite but dark minerals decreased, while K-feldspar and quartz increased. The chemical composition of various rocks are listed in Table 4. The pyroclastics of Xionger group isn't developed, but show a wide range of rock types. They include (1) pyroclast-lavas, brecciated lava, agglomeratic lava and tuffolava (2) lavo-pyroclastics, lavo-agglomerate, lavobreccia and lavotuff, (3) pyroclastics, agglomerate, volcanic breccia and tuff. The first two kinds are mainly rhyolitic, dacitic next, andesitic are very seldom. While the last kind is common in intermediate and acidic rocks. Hypabyssal or subvolcanic rocks occurred in the Xionger group, such as diabase, diorite porphyrite, andesite, dacite porphyry and quartz porphyry.

The chemical composition of the volcanites of the Xionger group show the following characters; (1) in Kuno's  $\text{SiO}_2$  vs  $\text{Na}_2\text{O} + \text{K}_2\text{O}$  diagram, the plot fall into alkaline basalt region; (2) in Wright alkalinity diagram, mostly fall in 1.6—3.5 part; (3) Peacock's indices fall in 53; (4) Rittmann's index are 1.8—3.3. So we concluded they belong to calc-alkaline series.

Table 4 Average chemical composition of volcanite of Xionger group

	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{TiO}_2$	$\text{Fe}_2\text{O}_3$	$\text{FeO}$	$\text{MnO}$	$\text{MgO}$	$\text{CaO}$	$\text{Na}_2\text{O}$	$\text{K}_2\text{O}$	$\text{Fe}_2\text{O}_3/\text{FeO}$
pyroxene andesitic porphyrite	50.75	15.26	1.12	3.87	7.61	0.15	5.23	5.20	3.42	2.13	0.51
andesitic porphyrite	55.22	14.33	1.23	4.26	4.13	0.14	4.03	4.34	3.14	2.83	0.69
ditto	62.50	12.85	1.17	3.88	5.32	0.12	1.92	2.40	2.67	3.23	0.72
dacite	67.11	12.49	0.84	3.75	3.14	0.08	0.76	1.27	2.35	5.30	1.19
rhyolite	73.32	11.65	0.45	3.04	1.98	0.03	0.44	0.50	1.47	5.38	1.54

Wangwushian volcanites happened in faulted active zone on the platform margin, most of them fall into the region B in Rittmann-Gottigen diagram. So they are orogenic volcanite. The  $\text{SrI}$  value is 0.7055—0.7096, con-juncted with tectonic background, it is suggested the magma generated from the base of the crust, belong to basaltic-andesitic magma.

#### B. Jinningian

These include the Erlangping group of north Qinling folded belt and Maotang group of south Qinling folded belt.

### (1) *Volcanite of Erlangping group*

They occurred in Erlangping-Liushanyong fault-depressed trough. The lower part are spilite-quartz keratophyre with a thickness of 2800—6500m, the upper part is flysch with some basic volcanics. Lavas include (a) spilite, this is the main part, get massive flowage, amygdaloidal and pillow structures, cryptocrystalline, diabase and poikilitic and porphyritic textures. Minerals are uraltite, albite, oligoclase, andesine-labradorite, chlorite and epidote. (b) keratophyre, happened as calations with massive structure or amygdaloidal structure, or even porphyritic, trachyoidal, poikilitic, micro-cryptocrystalline textures, main minerals are albite, oligo-albite, uraltite, biotite, chlorite, quartz etc, (c) quartz keratophyre, existed in the middle and lower parts with flowage-massive structure or some with amygdaloidal and massive structures, cryptocrystalline to aphanitic textures in the matrix. Chief minerals are albite, quartz. The chemical composition is show in Table 5.

Table 5 Average chemical composition of volcanites in Erlangping group

rock type	sample number	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	loss
spilite	28	50.81	15.40	0.80	3.78	6.65	0.23	7.01	8.06	3.44	0.90	0.21	2.40
keratophyre	6	62.83	15.02	0.72	2.79	4.57	0.23	6.55	9.41	0.25	1.13	0.26	1.13
quartz keratophyre	10	73.44	13.35	0.34	1.15	1.52	0.10	0.83	1.09	5.11	1.45	0.11	1.52

Pyroclastics isn't developed in this sequence, but from basic to acidic, from volcanic agglomerate and breccias to tuff and then to tuffite, all of them existed. Subvolcanics are also well developed, include pyroxene porphyrite, diabase, quartz albite porphyry, they commonly occurred as veins.

The analysis of 44 samples show volcanites of Erlangping group get rich in Na and poor in K. In AFM diagram, rocks evolved toward alkaline rich terminal, the plots show they belong to calc-alkaline series. In M. Gorai SiO<sub>2</sub> vs Na<sub>2</sub>O+K<sub>2</sub>O diagram, 50% of the samples fall within alkaline basalt region, 30% in high alkaline tholeiite region, while the plot of average composition fall in alkaline basalt region but near to the high alkaline tholeiite region. Peacock indice is 54. In Rittmann's index, 52% of the sample are 1.8—3.3, 34% are less than 1.8, 14% samples are greater than 3.3—9. The Rittmann index of average composition of spilite is 2.4, quartz keratophyre is 1.4, in Kuno's Al<sub>2</sub>O<sub>3</sub> vs Na<sub>2</sub>O+K<sub>2</sub>O diagram, 60% of the plots located in alkaline basalt region, 25% in tholeiite region. The above mentioned facts are very near, and denote volcanites of this group belong to (sodium) alkaline basalt to alkaline tholeiite series. This sequence happened in tectonic

active region and fault-depressed trough, so most of the plots in Rittmann-Gottigen diagram fall in B region, show the affinity of orogenic volcanite. According to a small amount of analysis on rare earth, the partition curve is flat. Spilitite show  $\Sigma \text{REE}=54-64$  ppm,  $\Sigma \text{Ce}/\Sigma \text{Y}=1.13-1.25$ ,  $\sigma \text{Eu}=1.06-1.09$ , the differentiation of REE is low with small positive Europium anomalies. The  $\text{SrI}$  value in the lower part is  $0.7029 \pm 0.0009$ , thus similar to the mantle derived magma.

## (2) Volcanite of Maotang group

This occurred in south Qinling geosyncline. Lower part is consist of quartz keratophyre and pyroclastics with a thickness of 430—1050m; the upper part is spilite and some pyroclastics with keratophyre, 1821—2387m thick. Sedimentary intercalations are common.

Spilite shows massive, flowage, amygdaloidal and scoria structures, some get pillow structure, phenocrysts get porphyritic, matrix get cryptocrystalline, diabasic, poikilitic and glassy textures, locally with globular. Main minerals are albite, urallite, chlorite and some pyroxene, hornblende and residual plagioclase. Keratophyre has local distribution with flowage, massive and amygdaloidal structures. Phenocryst are porphyritic, matrix get microcrystalline, aphanitic, micropoikilitic, trachytic and globular textures. Main minerals are albite, K-feldspar, quartz and sericite. Chemical composition is listed in Table 6.

Table 6 Average chemical composition of volcanites in Maotang group

rocktype	sample number	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	loss
spilite	28	47.23	2.11	16.10	7.67	6.10	0.24	6.04	6.04	3.27	0.72	0.27	1.02
keratophyre	6	53.74	0.66	16.05	3.54	2.97	0.12	3.44	3.71	4.81	1.14	0.06	3.24
quartz keratophyre	8	73.27	0.25	13.44	1.39	1.26	0.09	0.56	0.87	3.82	3.32	0.06	1.89

Table 7 Average chemical composition of volcanite of Yanshanian epoch

rock type	sample number	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	loss
andesite	11	60.19	0.84	15.75	4.49	1.87	0.10	1.92	4.28	4.05	3.82	0.36	2.27
dacite	2	67.10	0.49	14.09	2.39	0.68	0.05	1.39	1.48	4.00	5.07	0.17	2.28
rhyolite	6	72.38	0.38	13.10	2.73	0.64	0.03	0.31	1.20	3.13	4.37	0.13	1.86

Chemical composition shows the basic rocks have their plot in Kuno's

diagram,  $\text{SiO}_2$  vs  $\text{Na}_2\text{O} + \text{K}_2\text{O}$  and  $\text{Al}_2\text{O}_3$  vs  $\text{Na}_2\text{O} + \text{K}_2\text{O}$ , fall within alkaline basalt region, they are the same in M. Gorai diagram. Peacock indices are 52.6, Rittmann index are greater than 3.3, but diminished when evolved toward intermediate and acidic ends. The above facts denote this volcanic series should be put to weak alkaline, sodium rich, titanium rich basalt series. In Rittmann-Gottigen diagram they located in B region, i. e. orogenic volcanites.

### C. Yanshanian (early Cretaceous)

This part only existed in the northern slope of Dabieshan with a total thickness about 300—5200m. Lavas are andesite, dacite and rhyolite next; pyroclastics are volcanic brecciated lava, volcanic breccia and acidic tuff. Within Sinokorean platform volcanics of this age only existed in the southern part—Baofeng-Biyang depression with a thickness of 120—1727 m. Lavas are andesite, pyroclastics are volcanic breccia and acidic tuff.

Andesite show massive structure, locally with amygdaloidal and porphyritic structures. Matrix get vitric pilotaxitic and glassy textures. Phenocrysts are plagioclase ( $\text{An}=35-45$ ), pyroxene, hornblende and biotite, matrix are plagioclase, devitrified glass, and sanidine cryptocrysts. Dacite has massive and porphyritic structures, locally with amygdaloidal. Phenocrysts are plagioclase ( $\text{An}=32-40$ ), biotite, quartz, hornblende, locally has sanidine. Matrix are microcrystalline to micro-cryptocrystalline textures, partly glassy. Main minerals are feldspar, quartz and devitrified glass. Rhyolite get massive and flow structures, locally amygdaloidal or perthitic structures. Phenocrysts are plagioclase, orthoclase, sanidine, quartz, biotite. Matrix have micropoikilitic, globular and aphanitic textures. Main minerals are plagioclase, K-feldspar and quartz. Chemical composition are listed in Table 7.

The plot of chemical compositions in Kuno's  $\text{SiO}_2$  vs  $\text{K}_2\text{O} + \text{Na}_2\text{O}$  and Wright's Si-AR diagrams, most of the plot fall in alkaline region. Alkalinities are 1.81—3.86, calc-alkaline indices are 56, Rittmann's index are 3-4. Thus this sequence belongs to calc-alkaline series. They are rich in potassium and compared with the volcanite in southeast coast of China, the magma source should be crustal derived.

### D. Himalayan (Late Tertiary)

Volcanites of this epoch only happened in Sinokorean platform, belong to continental fissure eruptive products. They are olivine basalt, basaltic pyroclastics and subvolcanics. Total thickness is about 40—118m. Chemical compositions are  $\text{SiO}_2=41.50-48.36\%$ ,  $\text{TiO}_2=2.12-2.55\%$ ,  $\text{Al}_2\text{O}_3=13.10-14.95\%$ ,  $\text{Fe}_2\text{O}_3 + \text{FeO}=10.22-13.51\%$ ,  $(\text{Fe}_2\text{O}_3/\text{FeO})=1-1.5$ ,  $\text{MgO}=6.08-9.93\%$ ,  $\text{Na}_2\text{O} + \text{K}_2\text{O}=3.98-7.28\%$  ( $\text{Na}_2\text{O}/\text{K}_2\text{O}>1$ ), belong to alkaline to per-alkaline basalt. In Rittmann-Gottigen diagram it belongs to nonorogenic ones.

The common occurrence of deep ultrabasic xenoliths, total content of REE = 245.29 ppm,  $\Sigma \text{Ce}/\Sigma \text{Y} = 4.92$ ,  $\delta \text{Eu} = 1.09$ , these denote the rocks have a mantle source.

### III. The division of magmatic belt and characters of magmatism.

Based on the activities of earth's crust, tectonic background, rock genetic series, time and spacial distributions, the intrusives of Henan province may be separated into two regions and eleven belts, see Fig. 206, p395—396 in the text, Table 8. The petrological association and time of forming could made further subdivisions.

The main characters of petrozones: (1) Most of them extended in NWW trend with the exception of eastern slope of Taihengshan, which is NNE trend, all the directions of the petrozones are parallel to the regional tectonic trend. (2) They are commonly composed by intrusive activities of various ages, while in a particular zone, one stage may be the dominant constituent, sometimes there are two. In each zone, rock types are diverse.

(3) In most petrozones, rock bodies of early stage are smaller than those of the late stage, rock types evolved to simple. (4) In Sinokorean paraplatform, Caledonian and Variscan bodies are absent, only local Caledonian bodies have been discovered. However, in Qinling folded belt bodies of Caledonian and Variscan ages are very common with various rock types and constitute the main part of the related two petrozones. (5) Basic and ultrabasic rocks commonly elongated along deep faults, and acidic ones accompanied on the outer sides. (6) Yanshanian plutonic granite constitute the main body of many petrozones, hypabyssal granoporphry formed isolated subpetrozone when they are well developed. (7) No Indosinian body has been found, only some veins have been put in that stage.

The spacial and time distribution of intrusives of Henan province show the following characters. (1) Large scale eruption of intermediate basic rocks happened in Wangwushan and Jinning stages, (deep metamorphosed volcanics of Songyangian and Zhongtiaonian are not included), Wangwushanian andesitic volcanism happened on the faulted active belt along the periphery part of the platform, Jinningian basaltic volcanism happened within Qinling geosyncline. (2) Large scale acidic intrusive activities occurred in Variscan and Yanshanian stages, but no volcanism have been discovered in the meantime. (3) Basic and ultrabasic, intermediate intrusions belong to Caledonian stage in Qinling geosyncline, on Yanshanian to Himalayan in Sinokorean paraplatform. Moreover, as a whole, they located along deep faults. Eruptive

Table 8 Tectono-magmatic belt of Henan province

region	belt
Sinokorean	paraplatform
	<ol style="list-style-type: none"> <li>1. eastern slope of Taihangshan intermediate rocks of Yanshanian, ultrabasic rocks of Himalayan next</li> <li>2. Xiaoqinling acidic rocks of Yanshanian, next are intermediate-basic rocks of Wangwushanian and acidic rocks of Jinningian</li> <li>3. Xiongershan acidic rocks of Yanshanian, next are basic-ultrabasic and intermediate rocks of Songyangian</li> <li>4. Songshan-Jishan acidic rocks of Wangwushanian, next are intermediate acidic rocks of Songyangian and related ultrabasics</li> <li>5. Songxian-Lushan acidic rocks of Wangwushanian, next are alkaline rocks of Yanshanian</li> <li>6. Lushi-Queshan acidic rocks of Yanshanian, next are basic rocks of Jinningian, acidic rocks of Caledonian</li> </ol>
	Qinling folded belt
	<ol style="list-style-type: none"> <li>1. Guanpo-Yunyang-Shigunhe migmatic granite of Zhongtiaonian, acidic rocks of Yanshanian, next are acidic rocks of Wangwushanian</li> <li>2. Taipingzhen-Maoji intermediate rocks of Caledonian and acidic rocks of Yanshanian, ultrabasic and acidic rocks of the same epoch next.</li> <li>3. Wulichuan-Sizhuang-Xinyang acidic rocks of Variscan and Caledonian epochs, intermediate-basic rocks of the same epochs and acidic rocks of Yanshanian next.</li> <li>4. Tongbaishan-Dabieshan acidic rocks of Yanshanian, migmatic granite of Zhongtiaonian epoch and basic rocks of Caledonian next.</li> <li>5. Jingziguan-Naixiang intermediate-acidic rocks of Jinningian, ultrabasic rocks of the same epoch and acidic rocks of Variscan epoch</li> </ol>

activities gradually decreased in time, while intrusive activities enhanced in time.

Magmatic rock of Henan province may be separated into three types, according to their genetics, i. e., mantle derived, syntaxis and crustal reform-

ed series. (1) Mantle derived series has spilite-keratophyre association of Jinningian, basic and ultrabasic rocks of various ages. They are low in silica, poor in alkaline, but rich in MgO, FeO, CaO, low in REE with weak differentiation,  $\Sigma \text{Ce}/\Sigma \text{Y}=1-2$ ,  $\delta \text{Eu}$  is positive,  $\text{Srl}=0.7030-0.7034$ . (2) Syntaxis series has andesite-rhyolite association of Wangwushanian and Yanshanian stages, diorite-quartz monzonite-granodiorite-alkali granite-granophyre association. They get medium amount on  $\text{SiO}_2$  and alkali, LREE rich and with strong evolution,  $\Sigma \text{Ce}/\Sigma \text{Y}=6-8$ ,  $\delta \text{Eu}$  is weakly negative,  $\text{Srl}=0.7055-0.7096$ . (3) Crustal reformed series rocks are plutonic granite and migmatic granite of various ages. They are high in  $\text{SiO}_2$ , rich in  $\text{Al}_2\text{O}_3$ , abundant alkali,  $\text{K}_2\text{O} > \text{Na}_2\text{O}$ .

## **PART IV      REGIONAL METAMORPHIC ROCKS AND METAMORPHISM**

Metamorphic sequences are well developed in the province, and exposed in wide areas with a total extent of 23,000km<sup>2</sup>.

### **I . Main rock types of regional metamorphic rocks**

#### **A. Low grade metamorphics**

These rocks occurred in middle and upper Proterozoics, Carboniferous and upper Triassic of north Qinling region. They include slate subtype, silty sericitic slate, siliceous slate; metaclastic subtype, metavolcanic subtype and phyllite subtype, sericitic phyllite and quartz phyllite.

#### **B. Schists**

They happened in Archean to upper Proterozoic, from low green schist facies to amphibolite facies, and include mica schist subtype, various sericite schist, two mica schist, dolomitic schist and biotite schist; green schist subtype, metavolcanite; felsic schist subtype, different kinds of quartz and felsic schist; hornblende schist subtype; tremolite-actinolite schist subtype and other kinds of schist, such as graphite schist, talc schist, kyanite schist etc.

#### **C. Gneisses**

They existed is Archean to lower Proterozoic, include hornblende gneiss subtype, plagioghornblende gneiss, garnet plagioghornblende gneiss, tremolite hornblende gneiss; alkali feldspar gneiss subtype, hornblende calcite gneiss, mica albite gneiss, biotite K-feldspar gneiss, muscovite K-feldspar gneiss, garnet-sillimnite or biotite-monzogneiss; plagiogneiss subtype, biotite plagiogneiss, muscovite plagiogneiss, hornblende plagiogneiss etc.

#### **D. Felsic grainular rocks**

Existed within preCambrian beds, include quartzite subtype, arkose quartzite subtype, leucoliptinite and lyptinite etc.

#### **E. Marbles**

They also occurred in preCambrian beds, include marble, mica marble, tremolite marble, diopside marble, forsterite marble, apatite marble and dolomitic marble etc.

#### **F. Amphibolites**

They happened in preCambrian beds too, within metavolcanite series and composed of plagiogamphibolite and hornblendite.



### **G. Eclogites**

They happened within Taihua, Dabie, Sujaihe and Douling groups.

### **H. Granulites**

They occurred in Taihua, Dabie and lower part of Qinling groups, as garnet two pyroxene granulite, two pyroxene granulite and hypersthene granulite etc.

## **II . Main rock types of migmatitic rocks**

They may be separated into migmatic rocks, migmatite and homogenous migmatite.

### **A Migmatic rocks**

Rocks contain vein bodies of quartz, felsite or granitic fine grains, lower than 15% belong to this type, they may exist in various rock types except low grade one.

### **B. Migmatite**

Rocks in which vein bodies range to 15—50%, the boundaries between the vein and main bodies are remained clear to be seen, with the composition of granitic, plagiogranitic, pegmatitic, felsic, feldsparic etc.

The distribution of vein bodies suggest they include banded, brecciated, organ-like and straited types. Some division may be put forward by their base body type.

### **C. Homogenous migmatites**

They are high grade metarocks, the newly formed felsic minerals are up to 50%, base body has been deeply altered. Their occurrence are within Dengfeng, Taihua, Dabie and Qinling groups. Structures and textures of the rocks made them to be put into porphyroblastic homogenous migmatite, shady or filtrated homogenous migmatite, organ-like homogenous migmatite, straited homogenous migmatite etc.

As for migmatic granite, they have been described in magmatic rocks.

## **III . The basic characters of metamorphism**

### **A. The stage of metamorphism**

Regional metamorphism is closely related with tectonic movements, Six stages can be identified by their stratigraphic relationships, characters of metarocks, isotopic ages.

#### **(1) Songyangian**

This is a large scale regional metamorphism, green schist to low amphibolite facies changes occurred in Dengfeng group, high amphibolite facies in Taihua group and may locally reach to granulite facies, high amphibolite to granulite facies in Dabie group. Migmatization was common at the latest stage

of this period, homogenous migmatite and migmatic granite may appeared in restricted areas.

(2) *Zhongtiaonian*

Low green schist facies in Songshan group of Sinokorean paraplatform, green schist to high amphibolite facies in Qinling, Douling and Sujiahe groups of Qinling region, and granulite facies in the lower part of Qinling group. Zhongtiaonian migmatization was widespread in Qinling folded belt and induced extensive migmatic rocks and abundant homogenous migmatites and migmatic granites.

(3) *Wangwushanian*

This mainly occurred in Qinling folded belt, such as green schist to amphibolite facies in Xinyang group, but no migmatization has been reported.

(4) *Jinningian*

This metamorphic stage was localised in Qinling folded belt, on the north of Luanchuan-Queshan-Gushi deep fault, there existed a narrow zone, which is a part of Sinokorean paraplatform. Green schist facies, locally to amphibolite facies in Maotang and Erlangping groups, low green schist facies in Xionger, Guandaokou, Luanchuan and Rueyang groups, existed when they are near to deep faults.

(5) *Caledonian*

This only happened in Qinling folded belt, low green schist facies occurred in lower Paleozoic in Guanpo area. Sinian of both north and south Qinling have endured low and weak metamorphism.

(6) *Variscan*

This is chiefly the metamorphism of Carboniferous in northern slope of Dabieshan, low green schist facies.

In Wulichuan of Lushi, upper Triassic has been weakly metamorphosed, this may related with Yanshanian faulting.

**B. Division of meta-elements**

The province can be divided into two metaterranes, six subterranes, ten metazones by their metasequences, and distribution of metarocks, and also take account on tectonics and characters of metamorphism (see Fig. 265, p 526 in the text).

(1) *North China metaterrane*

This occurred on the north of Luanchuan-Queshan-Gushi deep fault.

a. Taihangshan-Songshan subterrane: The northern part is Taihangshan metazone, composed by Archean Dengfeng group with scattered outcrops in Huixian, Hebi and Lingxian. The lower part of the sequence is different kinds of gneiss (mostly hornblende gneiss), magnetite quartzite, migmatic leucopyrite, protoliths are argillaceous-arenaceous sediments. basic volcanics

and intrusives. The upper part is made of schists and lyptinite with marble without migmatite, belong to normal sedimentary formation. The southern part is Linshan-Songshan metazone, composed by Archean Dangfeng group and lower Proterozoic Songshan group exposed in Lingshan, Songshan, Yuxian, Linrue etc places. Dengfeng group, the lower part is lyptinite, gneiss and hornblendic rocks with some magnetite quartzite, locally strongly migmatized, protolithes are intermediate-basic volcanics and terrigenous clastics. While the upper part is various schist with marble without migmatite, protolithes are terrigenous clastics. Songshan group is consist of quartzite, sericite quartz schist, dolomite, protolithes are normal shallow marine to littorial deposits.

b) Xiao Qinling-Wuyang metazone. The metahorizons are Archean Taihua group, exposed in Xiao Qinling, Xiaoshan, Xiongershan, Lushan, Wuyang and their surroundings. The lower part is made of gneiss, plagiogneiss, migmatism is common. The upper part is gneiss, lyptinite and marble. Protolithes are basic-acidic volcanics with intercalations of argillite, silicite and carbonate.

c) Luanchuan-Queshan metazone. Metamorphism is clearly controlled by deep faulting, metabeds are those closely located along the fault, such as middle Proterozoic Xionger, Guandaokou and Rueyang groups, sericite schist, quartzite, marble etc. Protolithes are terrigenous rocks with the exception of Xionger group, which is intermediate-acidic volcanites.

#### (2) *Qinling-Dabie metaterrane*

This metaterrane situated on the south of Luanchuan-Queshan-Gushi deep fault

a) North Qinling subterrane. Tanghe-Huailongshi metazone is made of Kuanping and Taowan formations of Qinling group, lower Paleozoic and Sinian strata. Kuanping formation is consist of schist, gneiss, lyptinite, dolomitic marble locally migmatized, protolithes are sandy-muddy clastics with a part of intermediate-basic volcanites and carbonates. Taowan formation is marble, schist, gneiss, protolithes are muddy carbonate, calcareous and muddy rocks with a part of intermediate-basic volcanite. Sinian is calcareous conglomerate, dolomitic marble and schist, protolithes are pebbly, carbonaceous, muddy and dolomitic carbonates. Erlangping-Liushen metazone is composed of upper Proterozoic Erlangping group, the upper part is quartz schist, lyptinite, and marble, lower part is spilite-quartz keratophyre. Shiziping-Xinyang metazone is made of lower Paleozoic Qinling group, migmatic gneiss, gneiss, lyptinite, marble, and schist, protolithes are intermediate-basic to intermediate acidic volcanites, carbonates and calcareous-muddy rocks. Xiping-Pohe meta-

zone is made of middle Proterozoic Xinyang group and Carboniferous. Xinyang group is consist of quartz schist, plagioclase amphibolite, lyptinite and intercalations of marble and arkose quartzite. Protolithes are terrigenous, muddy-sandy or muddy-calcareous. Metacarboniferous only exposed on the west of Sangchen as slate and phyllite.

b) South Qinling subterrane. Douling-Xiaoshan metazone is composed by lower Proterozoic Douling group, gneiss, lyptinite and marble with extensive migmatization, protolithes are intermediate-basic volcanite, carbonaceous muddy sandstones and carbonate. Yaoyin-Maotoushan metazone is made of upper Proterozoic Maotang group, Sinian and Paleozoics. Maotang group is phyllite, sericite, schist, metasandstone, spilite-quartz keratophyre, protolithes are sandy-muddy rocks and intermediate-acidic volcanite. The metagrade of Sinian to Paleozoic are low.

c) Tongbaishan-Dabieshan subterrane. Hongyihe-Huwan metazone is consist of lower Proterozoic Sujiahe group, schist, gneiss, marble and some eclogite, quartzite, locally shown migmatization, protolithes are muddy rocks, carbonate and acidic-basic volcanite. Tongbai-Changchuyuan metazone is composed by Archean Dabie group, schist, gneiss with marble, quartzite, and leucolyptinite, migmatism was strong in the lower part. Protolithes are acidic volcanite with some basic ones and muddy-sandy rocks and carbonate.

### **C. Types of metamorphism**

The metamorphism of the province may be divided into two categories, regional metamorphism and regional dynamo metamorphism. There are regional metamorphism in Songyangian, progressive metamorphism in Dengfeng, Taihua and Dabie groups. As for Zhongtiaonian, the processes are rather complicated, regional dynamo metamorphism in north China metaterrane, regional metamorphism with progressive nature in Qinling and Dabie terrane. Wangwushanian is chiefly regional metamorphism, while Jinningian is mainly regional dynamo metamorphism, so did the Caledonian and Variscan metamorphism.

## PART V      TECTONICS

Henan province situated on two first order tectonic elements, i. e. , Sinokorean paraplatform and Qinling folded belt, many intensive crustal movements have activated in the region and made the region to be a very complicated area.

### I . Tectonic cycles and tectonic beds

The crustal movements and evolution of the region show polycyclic and uneven distribution characters. According to sedimentary facies, deposit formations, magmatic activities and igneous rock associations, regional metamorphism and migmatism, ore genesis, distribution of regional unconformities or disconformities, characters of structural deformation etc, the province get nine cycles and three types of tectonic beds, i. e. , geosynclinal, platformal and fault-depressional.

#### A. Basic character of tectonic cycle.

##### (1) *Songyangian*

This is equivalent to movement in late Archean time. Crust was mobile, intensive basic eruption and intrusion happened, normal fine clastics appeared in the end period. Songyang movement occurred at c. 2500Ma, this made the volcanosedimentary sequences intensively folded, changed to amphibolite-granulite facies under regional metamorphism and magmatism. Acidic intrusions invaded at the same time. Hehuai and Tongbai-Dabie continental neuclei were formed. This movement is expressed by the unconformity between Dengfeng and Songshan groups or Dabei and Sujiahe groups.

##### (2) *Zhongtiaonian*

This occurred in early Proterozoic. Songshan miogeosyncline happened at this time, and filled by a sequence of terrigenous and carbonate sediments. There are protoeugeosyncline in Qinling, and filled by basic volcanites in the early period, carbonate in the middle period, volcano-normal sedimentation in the late period. Zhongtiaonian movement happened at c. 1900Ma, Songshan miogeosyncline intensively folded and inverted and accompanied by green schist facies regional dynamo metamorphism. The Qinling protoeugeosyncline not only folded and inverted, but also endured amphibolite-granulite facies metamorphism and migmatism with local migmatic granites. The basement of Sinokorean paraplatform was formed at this time and gradually change to

Table 9 Chart on division of tectonic cycles and tectonic beds

Geological ages (Ma)		Tectonic movement	Tectonic cycle	Tectonic bed					
				Sino-Korean paraplatform		Qinling folded belt			
Cenozoic	Quaternary	late Himalayan	Himalayan  cycle	fault depression type	Himalayan  tectonic bed	fault depression type	Himalayan  tectonic bed		
	— 2.4 —							early Himalayan	
	Neogene								
— 25 —	V phase of Yanshanian	Yanshanian  cycle	Yanshanian  tectonic bed	Yanshanian tectonic bed					
Eocene					III phase of Yanshanian				
— 80 —									
Mesozoic	Cretaceous	Indosinian	Indosinian cycle	Indosinian tectonic bed		Indosinian tectonic bed			
	— 140 —								
	Jurassic								
— 195 —	middle Variscan early Variscan	Variscan  cycle	4th cover		Variscan tectonic bed				
Triassic						Caledonian			
— 230 —									
Paleozoic	Permian	early Caledonian	Caledonian  cycle				Caledonian tectonic bed		
	— 285 —								
	Carboniferous								
	— 350 —	Soulingian	Jinningian cycle	2nd cover		Jinningian tectonic bed			
	Devonian						Wangwushanian		
	— 375 —								
	Silurian	Zhongtiaonian	Zhongtiaonian tectonic bed						
	— 440 —								
	Ordovician			Songyangian	Songyangian tectonic bed				
	— 500 —								
	Cambrian								
	— 600 —	early Caledonian	Caledonian  cycle	3rd cover		Caledonian tectonic bed			
Sinian	Jinningian cycle						2nd cover		Jinningian tectonic bed
— 800 —									
early		Wangwushanian	Wangwushanian tectonic bed						
— 1000 —									
late	Zhongtiaonian			Zhongtiaonian tectonic bed					
— 1400 —									
early		Songyangian	Songyangian tectonic bed						
— 1900 —									
early	Songyangian			Songyangian tectonic bed					
Proterozoic		Songyangian tectonic bed							
— 2500 —									
Archean									

the development of platform. However, Qinling folded belt get its embroial shape at this age, and turned to fault-depression stage. The main expression is the regional unconformity between Xionger and Songshan groups, or Xinyang and Qinling groups or Sujiahe group too.

### (3) Wangwushanian

This existed in middle Proterozoic. Huaxiaong periplatformal depression occurred on the southwest part of north China. Abundant andesitic effusives accumulated in it to form andesite-rhyolite association and intermediate aci-

dic intrusives on the marginal part. Moreover, Xixia-Nanwan depression appeared in Qinling, and received intermediate-basic volcanites and flysch deposits, Wangwushanian movement happened at *c.* 1400Ma. Huaxiong depression get moderate fold without regional metamorphism. So we consider this stage as the transition between basement and cover in north China. Xixia-Nanwan fault-depression was totally folded and inversed, accompanied by green schist to amphibolite facies metamorphism. We would like point that the folding of Huaxiong depression was later than those of Xionger group in north China. The chief expression is the regional unconformity between Rueyang or Guandaokou group and Xionger group, or Erlongping and Xinyang groups.

#### (4) *Jinningian*

This appeared at late Proterozoic time. Cyclic platformal clastics to carbonate accumulated in north China. While in Qinling area, Erlongping-Liushanyan faulted geosyncline and south Qinling geosyncline existed. Intensive basic eruption happened and accumulate thick sequence of spilite-quartz keratophyre formation. Flysch and carbonate formation were also laid down in Erlangping trough. This cycle includes two main movements. Jinning movement occurred at *c.* 800Ma. In north China it get regional disconformity or local unconformity between Sinian and Luoyu group. However, in Qinling region, the two geosyncline were strongly folded and accompanied by green schist-amphibolite facies regional dynamo metamorphism and large scale intermediate-acidic intrusive activities. The chief expression is the regional unconformity between upper Sinian and Maotang group. Souling movement happened at *c.* 600Ma, and denoted by the regional disconformity or local unconformity between Cambrian and Sinian.

#### (5) *Caledonian*

This occurred in early Paleozoic. North China get platformal type carbonate. South Qinling was a miogeosyncline, belong to substable deposits, consists of carbonate and sandy-muddy rocks, deposits only occurred on the western part with carbonate and some volcanite in it. Vertical movement dominant at this period, faulting was also significant. Early Caledonian movement caused a regional disconformity between lower and middle Ordovician, basic eruption in south Qinling, intermediate intrusion in north Qinling. The middle Caledonian movement made the north China wholly uprised, and caused the absent of late Ordovician to early Carboniferous deposits. Basic to ultrabasic and intermediate-acidic magmatic activities happened along fault zones. At the meantime, south Qinling miogeosyncline remained to receive sedimentation. In late Caledonian movement, north China was still upris-

ed, deep fault of north Qinling became active and associated with basic-ultra-basic and intermediate-acidic magmatism. South Qingling miogeosyncline was uplifted too, and middle Silurian to early Devonian were absent, thus middle Devonian disconformable overlain above lower Silurian or Ordovician horizons.

#### ( 6 ) *Variscan*

This movement appeared in late Paleozoic. North China, as a whole, subsided, Carboniferous and Permian are continuous sedimentation. Variscan movement at the latest Carboniferous caused the folding and inverting of south Qinling miogeosyncline. Qinling geosynclinal system which located within Henan province was closed at this time. But western Qinling still remained as a trough, so the crustal movement and structural evolution were unevenly, non-unified developed. This cycle also caused the north Qinling to have large scale acidic intrusion and folding, weak metamorphism of Carboniferous strata occurred in the eastmost part.

#### ( 7 ) *Indosinian*

This occurred in Triassic. Triassic and Permian are continuous in north China, only the extent of sedimentation was diminished. Late Triassic coal bearing clastics filled fault depression along the fault. Indosinian movement occurred at the end of Triassic, it appeared as uplifting and flexuring in north China, disconformity between Jurassic and Triassic. In north Qinling, upper Triassic show moderate folding and local weak metamorphism.

#### ( 8 ) *Yanshanian*

The time span is Jurassic and Cretaceous. This is a important tectonic evolutionary stage in Henan province. Yanshanian cycle happened at the end of Jurassic and end of early Cretaceous, after that, the Mesozoic and earlier horizons were folded and received strong block faulting, this caused the forming of north China depression, ended the development of paraplatform, changed the former north-south differentiation to east-west separation in tectonic styles. The region was emerged to east China continental marginal mobile region. For the sake of totally activated, extensive intermediate-acidic intrusion and andesitic eruption along edge of depression occurred. This time span is also the stage for the formation of endogenetic and sedimentary ore deposits.

#### ( 9 ) *Himalayan*

This is the Cenozoic era, the stage of continental marginal mobile stage. In Eocene time, the crustal activities inherited the characters of Yanshanian age, differential block faulting were more intensified, fault depression quickly subsided and received extrathick petroliferous, gypsum-salt clastic forma-



tions. Late Himalayan expressed as large scale flexuring, original depressions continued to subside, its west part changed to rising, the junction position of depression and rise are the location for basic-ultrabasic eruption and intrusion.

## **B. Basic characters of the tectonic beds**

### **1. *Geosynclinal tectonic bed***

This includes Songyangian tectonic bed (Dengfeng, Taihua and Dabie groups), Zhongtongian tectonic bed (Songshan, Qinling, Douling and Suliahe groups), Wangwushanian tectonic bed (Xinyang group), Jinningian tectonic bed (Erlangping, Maotang, and Sinian of Qinling region), Caledonian tectonic bed (lower Paleozoic of southern Qinling, Paleozoic of northern Qinling) and Variscan tectonic bed (Devonian and Carboniferous of southern Qinling).

### **2. *Platformal tectonic bed***

This distributed in Sinokorean paraplatform, from bottom to top there are intermediate (basic) volcanite—acidic volcanite—uniterrogenous clastics—magnesium carbonate—terrigenous clastics—carbonate—coal bearing ferro-aluminous clastics—carbonate—terrigenous coal bearing—red terrigenous clastics, these composed a complete sequence of paraplatform. This reflect that after the consolidation of basement, the region had passed from active and through graduation to relative stable. In other words, we can separated them to four parts; the first is Xionger group which behas transition nature of geosyncline to platform, the second is middle to upper Proterozoic, the third is Cambrian to lower Ordovician, the fourth is middle Carboniferous to upper Triassic. The total thickness reaches 15000m.

### **3. *Fault-depression tectonic bed***

Since Jurassic time intensive differential movement or block faulting are the main tectonic style, and laid the formation of a series of fault-depressions which are separated each other, with various dimensions, and shown different orientations. Among them, thick continental clastics and volcanite accumulated. Sedimentary formations and contact relationship between formations suggest that they include three tectonic beds, i. e., Indosinian bed (upper Triassic in northern Qinling), Yanshanian bed (Jurassic and Cretaceous) and Himalayan bed (Eocene to Quaternary).

## **II . Deep faults**

According to geological and geophysical data, Henan province get eight deep faults, seven of them are lithospheric and the rest are crustal. They may be grouped to NNE and NWW system by their spacial distribution.

### **A. NNE deep faults**

They situated within Sinokorean paraplatform, north of Jiaozuo-Shangqin deep fault, they are eastern slope of Taihangshan and Liaocheng-Lankao deep faults, all belong to extensional high angle normal fault. The activities of the deep fault induced the appearance of Tangyin and Dongpu fault-depressions. Eastern slope of Taihangshan deep fault is also the location of basic-ultrabasic intrusion and extrusion zone in Himalayan stage and presented as a tectono-magmatic belt. These two deep faults formed in Yanshanian stage, and strong activated in Himalayan stage, and are still active now with earthquakes, so we believe it is lithospheric.

### **B. NWW deep fault**

This directional faults include Jiaozuo-Shangqin, Luanchuan-Queshan-Gushi, Waxuezi-Yahokou-Minggang, Zhuyangguan-Xiaguan-Dahe, Xiguanzhuang-Zhenping-Guizhan-Meishan, and Mojiaya-Neixiang-Tongbai-Shangcheng, totaling to six. The first one situated on Sinokorean paraplatform and are crustal, all the rest are located within Qinling folded belt and belong to lithospheric. The second one is the divided between Sinokorean paraplatform and Qinling folded belt, the other faults are 2nd or 3rd order tectonic element's dividing lines. NWW deep faults not only strongly influenced the tectonic framework of the province, but also effected the sedimentation, magmatic activities, metamorphism, ore genesis and tectonic evolution since early Proterozoic. These faults formed rather early (before Jinningian), long activated and change their nature with time.

## **III . Tectonic elements**

Henan province may be divided into two first order, ten second order and 29 third order tectonic elements by the mobilisation of the crust, tectonic evolutionary history, cyclicity characters and the combination of geological structures (see Fig. 295, p 628 in the text)

### **A. Sinokorean paraplatform**

This include the area north of Luanchuan-Queshan-Gushi deep fault, has double crustal structure. The basement is Archean Dengfeng group and Taihua group, which have passed through medium to deep metamorphism, low grade metasediments of Songshan group can also be included, the total thickness reaches 8000m. Songyangian and Zhongtiaonian movements made the strata intensively folded and changed to stable basement, two regional high angle unconformities existed within the basement strata, i. e. , the top of Dengfeng and Songshan groups. Middle Proterozoic Xionger group is an andesitic-rhyolitic series with a thickness of 7580m, shown active character. This sequence was folded during Wangwushanian movement and bounded by

unconformities above and below. The structural style and grade of metamorphism are similar to the overlain horizons, but the nature of strata is quite different. Thus we suggest it to be the transition horizon between the basement and the cover (put to the first tectonic bed preliminarily). The cover horizons are middle Proterozoic Rueyang group of Guandaokou group to Triassic, totalling to 8000m. Yanshanian movement caused the folding of the cover, but haven't received any metamorphism. Four unconformities lay among the cover, i. e. the bottom of Sinian, Cambrian, middle Ordovician and middle Carboniferous, and representing Jinningian, Soulingian and Caledonian movements of the Sinokorean paraplatform. The influence of Yanshanian movement is rather strong, it caused the folding of the cover, the rising of western hills, and induced intensive block faulting and subsidence of the eastern part which get a great amplitude of subsidence. The platform was mobilised, new differentiation happened, the crustal variety was changed from north-south to east-west, North China depression started at this time. So we may say the Yanshanian movement made the Province entered into east China continental marginal mobile belt. The depositional thickness of Meso-Cenozoic is greater than 8200m. In conclusion, we would like to say, in the tectonic evolution of Sinokorean paraplatform, Zhongtiaonian and Yanshanian movements are the turning era, the first formed the basement and caused the region entered into platformal developing stage, while the latter made the region emerged into continental marginal mobile stage. Mineral deposition show variations within the three tectonic beds, iron and gold in the basement, coal and aluminium in the cover, oil, gas, gypsum, salt and nitrate in the uppermost part. As for the endogenetic ores, they concentrated on the marginal fault zones and accompanied with Yanshanian magmatic activity.

Structural styles and their extensions are quite different between localities and ages, and this was caused by the differences between various tectonic stages. Basement structures are complicated with tight or overturned linear folds. They are north-south with some superpositions in Taihengshan and Songshan, northwest in Xiaoqinling and Wuyang region with some superposition of north-south trend. The direction of faults are similar to the folds, thrusts are the main form. However, the folds of the cover are simple, open and gentle anticlines and synclines. The general tectonic trends are north-south on the north of Jiaozhuo-Shangqiu deep fault, or near east-west south of it, but around Lushi-Luanchuan area, the influence of northward thrusting and deep fault made the cover beds exhibit linear folds or even overturned and accompanied with green schist facies metamorphism. Faults are abundant in the cover, and cut the province into rhombic blocks.

High angle normal faults are the chief forms, some overthrusts also have been found, for example in Batai area, south of Wuyang, Archean overthrusts above Rueyang group. Other data suggest the overthrusts and nappes are in east-west direction. No folding has been discovered in Mesozoic-Cenozoic basins, they only have tilting, flexuring or subsiding. At the meantime, faulting is common, mostly normal faults, these laid the foundation of the intermingling of grabens and horsts, spaced in near equidistancial. Structural direction within the depressions are north-south on north of Jiaozhuo-Shangqiu deep fault, or east-west south of it.

### **B. Qinling folded system**

This includes the vast area south of Luanchuan-Queshan-Gushi deep fault, and composed of north Qinling, south Qinling and Tongbai-Dabie zones. These are polycyclic developed geosynclinal system and complicated long activated tectonics, no cover bed has been found yet. Archean Dabie group situated on the southern part, may be regarded as an old nuclei, with a total thickness of 5700m. Lower Proterozoic Qinling, Douling and Sujiahe groups are the volcano-sedimentary formations of the proto Qinling geosyncline, they endured intensive folding and amphibolite (locally reach granulite facies) regional metamorphism and extensive migmatism. They are the base of the folded system. Late stage NWW deep fault cut them into pieces, thus they exposed on north and south Qinling-Tongbai and Dabieshan respectively, their thickness are 12700, 3900 and 4410m. Xinyang group located between Qinling and Tongbai-Dabie, it is a middle Proterozoic fault-depressional geosynclinal volcano-flysch formation, intensively folded and get green schist to amphibolite facies regional metamorphism during Wangwushanian movement. The exposed thickness reaches 220-8900 m. Erlangping group exposed in north Qinling, it is a spilite-quartz keratophyre formation of early period of late Proterozoic, 4800-10000m thick, belongs to fault-depressional geosyncline. Maotang group exposed in south Qinling, also a spilite quartz keratophyre formation, belongs to early period of late Proterozoic Qinling eugeosyncline, 2400-4400m thick or more. Jinningian movement made the above two geosynclines folded and inversed, accompanied by green schist facies (locally amphibolite facies) regional metamorphism. Basic to ultrabasic intrusions appeared in the early stage, intermediate acidic ones on the late stage. The Sinian to Carboniferous strata exposed on the southern part of south Qinling belong to miogeosynclinal terrigenous clastic to carbonates with some basic volcanite, maximum thickness is 8900m. Variscan movement caused this part folded and inversed, and ended the geosynclinal development of the Qinling region, the region was changed to be

an uprised mountainous area and get block faulting. We would like to point out that the lower Paleozoic volcanite-carbonate formations on the western section of the north Qinling may be regarded as Caledonian folded belt and has extensive basic-ultrabasic and intermediate-acidic intrusive activities during the Caledonian time, thus we should say north Qinling had received the superposition of Caledonian folding. Besides that, on the eastern part of north Qinling there existed Carboniferous coal bearing molasse, more than 7700m thick, the containing fossils show the mixture of south and north China character or affinities. This sequence was folded and weakly metamorphosed. The Mesozoic and Cenozoic of the Qinling region belong to fault depressional with many types, volcanites, red molasse, petroliferous and evaporates. All the deep faults are active in Yanshanian time, large scale acidic magmas intruded and formed granite zone in Qinling. In conclusion Qinling folded belt has passed through four stages, early Proterozoic, middle Proterozoic, late Proterozoic and Paleozoic, it has endured several orogenic movements and then finally consolidated. In Mesozoic-Cenozoic time, strong faulting also effected it.

The structures of the Qinling folded belt are rather complicate, both folds and faults are abundant. The main structural trends are NWW. North Qinling is a mega-anticlinorium, folds are tight, some are overturned, superposition are common. There may exist overthrust, for Qinling group has overlain above upper Triassic or Erlanping group. The northern part of south Qinling is an anticlinorium with tight folds, while the southern part is open synclinorium with simple folds. Tongbai-Dabieshan is a mega anticlinorium, extended in NWW, but NW or NE anticlines and synclines have been seen in the core of Dabie group, this denotes there existed structural superposition. Among faults, the most important ones are five deep faults, composed the Qinling fault system. Most of them started during Zhongtiaonian and Wangwushanian stage. Analysis on intermediate basic and ultrabasic bodies, their structural relationships and analysis on tectonites denote that the faults have been acted for many times. They are normal faults in the early period, reverse or thrust on the late period. NE faults also existed, but acted in later time at Yanshanian movement such as normal-transverse fault of Shangcheng-Macheng.

## **PART VI    GEOLOGICAL EVOLUTIONARY HISTORY**

The geological history of Henan province may be traced back to Archean, c. 3 billion years ago. This history can be divided into four stages by the geological events happened, see Table 10. Furthermore the province can be separated into two regions, according to the spacial distribution and unbalanced development of the crustal evolution.

### **I . Main characters of crustal evolution**

The crust has passed through a polycyclic spiral development from oceanic to continental. Archean is the time of oceanic crust forming and the foundation of old neuclei, continental crust increased quickly during early Proterozoic, oceanic crust greatly diminished and move southward in middle and late Proterozoic, and at this period, the formed continental crust has been splited and then amalgumated, from Sinian to Triassic the crust is relatively stable, the province is differentiated in east-west direction and emerged to continental marginal mobile stage after Mesozoic. Or in short this history can be summerised as active—relative stable—active. It should be noticed that the mobilities of the crust are uneven both in time and in space. For example, north China had entered to stable paraplatform stage in middle and late Proterozoic, while at the same time, oceanic and continental crust coexisted in Qinling, miogeosyncline and eugeosyncline parrellel developed. The activated part gradually moved southward, but sometimes may be reversed. For example, in the early period of middle Proterozoic, the basement of north China has been consolidated, on the marginal fault depression formed which is synchronous with the formation of fault trough geosyncline in Qinling area, this lead the accumulation of andesite-rhyolite association of Xionger group. Other case is the coexistence of north Qinling fault trough geosyncline and south Qinling eugeosyncline during late Proterozoic. After Mesozoic, east-west differentiation became prominent. This is the chief character of spiral development and we must take that in mind.

### **II . Characters of evolution**

Six crustal movements occured in the province, i.e., Songyangian, Zhongtiaonian, Wangwushanian, Jinningian, Variscan and Yanshanian, among them

Table 10 Chart on geological evolution

stage	age	crustal movement	evolution characters
Jurassic —Quaternary	Quaternary	Himalayan	The differentiation of the crust changed from north—south to east—west. Block faulting is the main tectonic movement. North China depression formed. The province entered into continental marginal mobile stage
	2.4		
	Neogene		
	25		
	Eocene		
	80		
	Cretaceous		
Sinian —Triassic	140	Indosinian	Sinokorean paraplatform was stable, the crust wholly rised at the end of middle Ordovician and sea regressed. Resubsided after middle Carboniferous and sea transgressed.  Qinling geosyncline move southward, south Qinling miogeosyncline developed, Variscan movement happened folded belt formed.
	Jurassic		
	195		
	Triassic	Variscan	
	230		
	Permian		
	285		
	Carboniferous		
	350	Caledonian	
	Devonian		
	375		
	Silurian	Soulungian	
	440		
	Ordovician		
	500	Jinningian	
Cambrian			
600			
late Sinian			
1000			
Proterozoic	early	Wangwushanian z hong-tianian	Crust splited, eu/miogeosyncline coexist, Sinokorean basement formed in Wangwushanian movement and entered to platform stage. Faulttrough and eugeosyncline coexist in Qinling Ocean closed in Jinning movement, Qinling folded belt formed
	1000		
	late		
	1400		
	early		
Early Proterozoic	1900	Songyangian	Oceanic crust changed to continental, old nuclei formed, eugeosyncline dominant, Sinokorean basement formed at th end of this stage, proto Qinling appeared, north China and Qinling crust colliaded
	Early Proterozoic		
	2500		
Archean	Archean		

the second and the last are significant. Zhongtiaoian movement caused the formation of the basement of Sinokorean paraplatform and proto Qinling geosyncline, NWW structural framework started, deep faults activated since then, fault trough geosyncline and platform coexisted, this started the north-south differentiation afterward. Yanshanian movement made the cover of Sinokorean paraplatform to have east-west folds and greatly activated, block faulting became dominant, western part rised highly, while the eastern part subsided with the formation of north China depression. Since that the province emerged into east China continental marginal mobile belt. After Yanshanian movement, north-south structures (especially faults) became active, east-west differentiation are the main type.

In the course of evolution, crustal vibrations are common and frequent, among them two are important. Caledonian movement caused the whole north China uplifted, late Ordovician to early Carboniferous are absent, while in Qinling region, middle Silurian to early Devonian are lacked. Variscan movement induced totally subsidence, and lead the second widespread transgression in north China, and offered a paralic environment for late Paleozoic.

### **III . Main characters on the evolution of sedimentary formation**

Sedimentary formations are closely linked with tectonic conditions. In Archean time, the crust was mobile, basic volcanite was the chief form and intercalated with intermediate-basic and ultrabasic complex, flysch appeared in the late period and associated with iron formations. While during early Proterozoic, we can divided out mobile and substable regions already, thus the sedimentary formations include two types. Subabyssal to shallow marine volcanite clastic formation in eugeosyncline, such as proto Qinling eugeosyncline; miogeosyncline has terrigenous clastics to carbonate formations such as Songshan miogeosyncline, with iron and phosphorous ores in them. During middle Proterozoic to Paleozoic, two main tectonic elements occurred, platform and geosyncline, thus sedimentary formations get two types. Formations include (1) continental marginal eugeosyncline with spilite-quartz keratophyre formation, such as Maotang group in south Qinling, (2) intra-continental fault-trough geosyncline, if it is a mobile belt, it get spilite-quartz keratophyre and flysch formations, such as Erlangping group of north Qinling, or if it situated on transitional zone, andesite-rhyolite association laid down, such as the Xionger group on the southwest margin of Sinokorean paraplatform, (3) continental marginal miogeosyncline, carbonate forma-



tions, such as the Sinian to Carboniferous formations in south Qinling, (4) platformal sedimentary formations, include four types, terrigenous clastics, carbonates, coal bearing terrigenous clastics and red terrigenous clastics, with associated iron, coal and aluminium ores. Mesozoic and Cenozoic get inland basinal sediments, terrigenous clastic-petroliferous, terrigenous coal bearing, terrigenous salt-gypsum-nitrate and red terrigenous formations. Besides these, there still exist volcano-sedimentary formation. At this stage, ores are coal, oil-gas, salt-nitrate, gypsum, bentonite and pearcrite.

## **V. Main evolution of paleontology**

Biotas evolved in the 3 billion years long period. Planktonic faunas appeared in early Proterozoic and flourished in middle and late Proterozoic. Benthonic brumbing and planktonic animals occurred in early Paleozoic, high rank plants happened in late Paleozoic, vertebrates started in late Permian, mammoth and reptile flourished in Mesozoic, paleo homospecies appeared in middle Pleistocene.

## **VI. Main character of magmatic activity**

Magmatic activities are closely related with the differentiation of the earth's crust and tectonic conditions. Every tectonic movement has its own magmatic representation, but differed in type and nature. Songyangian movement get basic eruption, belongs to oceanic tholeiite series, basic-ultrabasic intrusions associated, or acidic ones in the late stage. Zhongtiaonian movement show intermediate to basic eruptions with small amount of acidic intrusion in the late stage. Wangwushanian movement has eruption of andesitic magma and some basic or acidic intrusive actions. Jinningian movement lead the largest scale basic eruption since Archean time, and accompanied by intermediate-basic intrusions. Caledonian movement induced another large scale intermediate-basic to ultrabasic intrusions, while eruption only happened in localised areas, intrusive activity enhanced in late stage. Variscan movement only caused acidic intrusion. Yanshanian magmatic activity is rather strong, acidic intrusive activity is widespread and composed the tectono-magmatic zones of the province, at the mean time, intermediate (basic) magma was restricted in certain small areas. The magmatic action of Himalayan movement is weak, basic-ultrabasic are the chief form. In short the magma is basic intrusion and extrusion before early Paleozoic, and acidic after it with some eruption. However, when entered into Himalayan stage, basic-ultrabasic are

the main source, both intrusion and eruption existed. The differentiation of the deeper part may be strengthened.

---

**Geological Publishing House**  
**Address: Xisi, Beijing, China**

**Bureau of Geology and  
Mineral Resources of  
Henan Province**  
**Address: Zhenzhou, Henan  
Province, China**

the main source, both intrusion and eruption existed. The differentiation of the deeper part may be strengthened.

---

**Geological Publishing House**  
**Address: Xisi, Beijing, China**

**Bureau of Geology and  
Mineral Resources of  
Henan Province**  
**Address: Zhenzhou, Henan  
Province, China**

the main source, both intrusion and eruption existed. The differentiation of the deeper part may be strengthened.

---

**Geological Publishing House**  
**Address: Xisi, Beijing, China**

**Bureau of Geology and  
Mineral Resources of  
Henan Province**  
**Address: Zhenzhou, Henan  
Province, China**