Mesozoic thrusts and extensional structures in the Daqingshan orogen, Inner Mongolia, and their temporal and spatial relationship*

QI Guowei[1], ZHANG Jinjiang[1]**, WANG Xinshe[2] and GUO Lei[1]

(1. Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education, China; School of Earth and Space Sciences, Peking University, Beijing 100871, China; 2. Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China)

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Abstract Three large-scale thrusts developed in the Daqingshan orogen, Inner Mongolia, with a northeast-east trending from Louhuashan to Suletu are described in this paper. These northwest-directed thrusts, together with the four tectonic belts (or tectonic sheets) separated by these faults, formed a typical thrusting system. The originally defined Hohhot metamorphic core complex may be a tectonic sheet, making the uppermost tectonic unit of the thrusting system and truncated by the Daqingshan detachment fault on top. The existing tectono-chronological studies showed that the thrusting of this region possibly happened at the same time as the extension along the top detachment fault. This presents that the contraction and extension in Daqingshan orogen were probably simultaneous. The structural pattern of the Daqingshan orogen can be correlated to the Himalayan orogen, and models for simultaneous thrusting and detachment in Himalaya may give a hint for explaining the development of the Daqingshan orogen.

Keywords: **Daqingshan, thrust, metamorphic core complex, detachment fault, contraction-extension transform, Himalaya.**

Generally, a collisional orogen tends to transform from contraction and thickening in an early stage to extension and thinning in a late stage. This contraction-extension transform is very significant because it defines the subsequent tectonic framework, tectonothermal processes and distribution of geological resources in the region[1—4]. North China plate is confined by several tectonic systems and experienced a complicated geological history. Since Mesozoic, this plate began to undergo a tectonic transform, and the continental dynamic regime shifted from contraction and thickening to extension and thinning[5—8]. During the transform, both large-scale thrusts of Indochina-Yanshanian Period and extensional structures of Mesozoic formed in this region. For example, the Mesozoic intra-continental orogeny formed lots of large-scale thrusts from Xinjiang to eastern Hebei, along the northern margin of the North China plate. These thrusts include those recognized earliest in China and the northern margin of North China plate has been a model region for the studies on thrust-related structures in China.[9—12]. Meanwhile, metamorphic core complexes developed extensively in this region, such as Yagan and Louzidian metamorphic core complexes, and Mesozoic extensional structures in this region can be compared to those in Cordillera of USA[13—16].

In the Daqingshan orogen, a large-scale thrusting system, made up by a series of northward thrusted sheets, developed in Shiguai area just west to our study region[17] while a metamorphic core complex was in the region—the Hohhot area. This metamorphic core complex was thought to be formed by the collapse of the thickened crust of the orogen[18—20]. Obviously, both thrusts representing thickening and extensional structures standing for thinning developed adjacently in the Daqingshan orogen. This provides an ideal geological location for investigating the genetic relationship and transform process between the contractional and extensional structures. This also makes the region favorable for studies on transform from contraction and thickening to extension and thinning in continental lithosphere. Moreover, recent studies showed that the ages of the thrusting[21] in this region is consistent with those of the extension in the metamorphic core complex[18]; this may give a new hint for revealing transform fashion and process of the continental dynamic regime in North China.

This study showed that: the principal structural pattern of the Daqingshan orogen is a thrusting sys-

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** To whom correspondence should be addressed. E-mail: zhjj@pku.edu.cn

tem with hanging walls thrusting northwestwards; the uppermost tectonic unit of the thrusting system is the originally defined Hohhot metamorphic core complex truncated by the Daqingshan detachment fault on top; such a structural pattern and the simultaneousness between the thrusting and the detachment faulting show that the development of the Daqingshan orogen may be similar to that of the Himalayan orogen to a certain extent.

1 Geological setting

The Daqingshan orogen, extending nearly 200 km along the northern margin of the North China plate, is located in the western segment of Inner Mongolian anticlinorium which composes the middle segment of Tianshan-Yinshan latitudinal belt. It is also an important component of the western Yinshan-Yanshan intra-continental orogen. It is bounded by the Cenozoic Hetao faulted basin to the south, and neighbored to the Paleozoic Tianshan-Xing'anling-Mongolian orogen to the north.

Our study region is located in the eastern Daqingshan orogen from Louhuashan in the west to Suletu in the east (Fig. 1). Petrologically, the orogen in this region is mainly composed of pre-Cambrian metamorphic rocks and Mesozoic sedimentary strata. The pre-Cambrian rocks constitute the crest of the Daqingshan Mountain and these rocks include Archean marble and gneiss, Proterozoic gneissic granite and Proterozoic low-grade metamorphic rocks. The Mesozoic strata distribute along the two flanks of the Daqingshan Mountain. The Jurassic (possibly upper Jurassic) strata mainly developed in the northern flank and it is chiefly composed of mauve and gray-white conglomerate, sandstone, siltstone and mudstone, some of them experienced slight metamorphism. The lower Cretaceous red conglomerates were found in the southern slop of Daqingshan, clasts and pebbles in them are mainly metamorphic rocks from the crest of the Daqingshan Mountain.

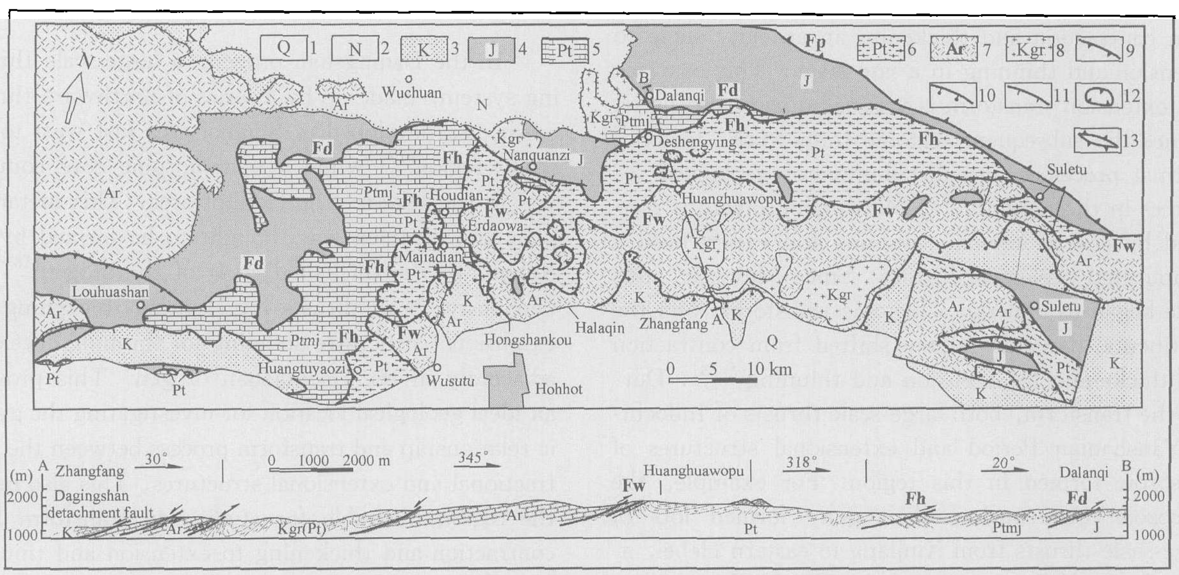

Fig. 1. Structural map of the Daqingshan thrusting system. (1) Quaternary sediments; (2) Tertiary sediments; (3) Cretaceous sediments; (4) Jurassic sediments; (5) low-grade metamorphic belt (Proterozoic); (6) gneissic granite (Proterozoic); (7) metamorphic crystalline sheet (Archean); (8) Cretaceous granite; (9) thrust; (10) Daqingshan detachment fault; (11) normal fault; (12) klippe; (13) tectonic window. Fp, Panyangshan thrust; Fd, Daqingshan thrust; Fh, Huangtuyaozi-Majiadian-Deshengying thrus; Fw, Wusutu-Huanghuawopu-Suletu thrust.

2 Daqingshan thrusting system

The main structures, chiefly folds and thrusts, in the study region have a nearly east-west trend (Fig. 1). From north to south, three large-scale thrusts developed in this region, which separated the Daqingshan orogen into four tectonic sheets thrusted northwestwards.

2.1 Main thrusts

Three thrusts formed in the study region. They are from north to south successively (Fig. 1):

(1) The Daqingshan thrust (Fd)[11]: From Louhuashan, northward to Wuchuan, then eastward to the east of Deshengying, this fault is the outmost thrust of the Daqingshan thrusting system, which

juxtaposed the allochthonous Proterozoic low-grade metamorphic rocks over the autochthonous Mesozoic strata.

(2) Huangtuyaozi-Majiadian-Deshengying thrust (Fh): From Huangtuyaozi northwards to Majiadian, then eastwards to Maoduqing, and merged with Daqingshan thrust east to Deshengying, this fault thrusted the gneissic granite of Proterozoic over the low-grade metamorphic rock of Proterozoic.

(3) Wusutu-Huanghuawopu-Suletu thrust (Fw): From the west of Wusutu northwards through Erdaowa and Wudaogou, and then through Huanghuawopu eastwards to Suletu, this thrust juxtaposed the southernmost metamorphic crystalline sheet over the gneissic granite.

2.2 Main thrusted sheet

In the study region, the Daqingshan orogen is separated by the above thrusts into several nearly east-west strike tectonic sheets, and therefore forms a typical thrusting system (Fig. 1). According to the tectonic locations from north to south, this thrusting system is formed by the following four tectonic belts (or tectonic sheets):

(1) Outside belt: north to the Daqingshan thrust. This belt is chiefly composed of Jurassic strata. It is located north to the thrusting system, not belonging to the system, but is the autochthon affected by the thrusting system.

(2) Low-grade metamorphic belt: south to the Daqingshan thrust and north to the Huangtuyaozi-Majiadian-Deshengying thrust. This belt consists mainly of the Majiadian Group of Proterozoic, which is a series of low-grade metamorphic rocks such as schist, phyllite and marble. With great change in width, this belt becomes narrower to the east, and dies out east to Deshengying.

(3) Gneissic granite belt: located between the Huangtuyaozi-Majiadian-Deshengying thrust and the Wusutu-Huanghuawopu-Suletu thrust. This belt has an average width of about 10 km and is composed of gneissic granite of Proterozoic.

(4) Metamorphic crystalline sheet: located in the southernmost of the thrusting system, south to the Wusutu-Huanghuawopu-Suletu thrust. This belt is chiefly composed of Archean gneiss and marble, together with some Yanshanian plutons.

The above four sheets become older successively from north to south, and the older sheets overly the younger ones. This structural pattern is consistent with the thrusting system newly found in the area just west to the study region[21]. The metamorphic crystalline sheet in southernmost belt, is the originally defined Hohhot metamorphic core complex which was truncated by the Daqingshan detachment fault on top[18].

3 Structures and kinematics of the Daqingshan thrusting system

Structural and kinematic analyses showed that the three faults are thrusts with hanging walls moving to the northwest, forming a typical thrusting system. Because the northernmost Daqingshan thrust has been studied very well[11], here we only describe the structures and kinematics of the other two thrusts.

3.1 Huangtuyaozi-Majiadian-Deshengying thrust

Along this fault, the Proterozoic gneissic granite was thrusted over the low-grade metamorphic rocks of Proterozoic. The gneissic granite belongs to rocks in middle-deep structural level, while the underlying low-grade rocks belong to shallow level. These low-grade rocks usually are phyllite, meta-sandstone, meta-conglomerate and slightly recrystallized marble, and the highest grade of them is schist. The contrast in metamorphic grades clearly indicates a thrusting contact between the two walls of the fault.

Beside the abandoned military camp along the old Hohhot-Wuchuan highway (Figs. 2(a), 3(a)), the hanging wall is composed of gneissic granite, in which the foliations dip eastwards with a dip angle of 14° and the lineations plunge S65°E with plunge angles of about 10°. The footwall consists of low-grade slate, phiyllite and marble, in which the foliations dip eastwards with a dip angle of 25° and the lineations plunge S25°E with angles of about 13°. The fault plane is parallel to the foliation of the hanging wall and a 5 m-thick chloritic mylonitic zone formed at the base, in which the S-C foliation indicates a northwestward thrusting (Fig. 2(b)). A 1 m thick layer of schistose tectonite developed on top of the footwall, and there are basic dykes intruded parallel to the fault plane. Closed-spaced cleavages formed in the schistose tectonites which dip eastwards with a dip angle of 55°. This also indicates a northwest-directed thrusting of the hanging wall.

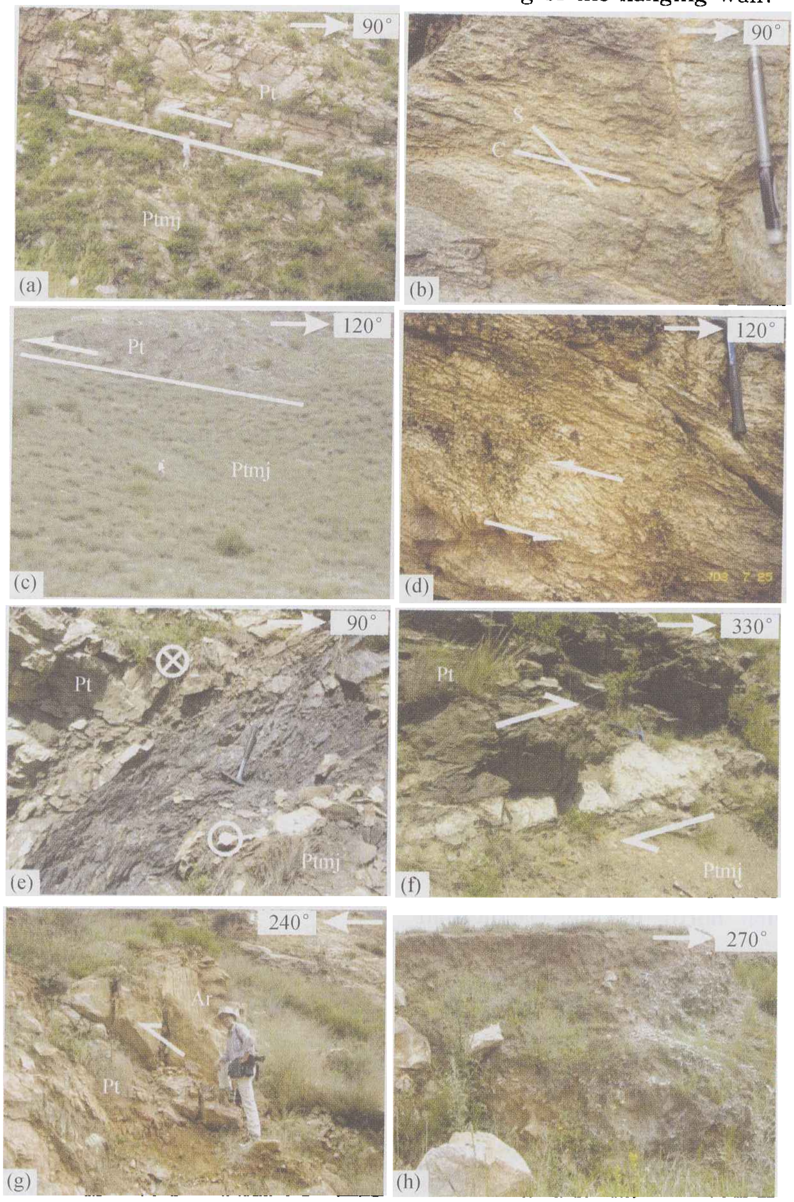

Fig. 2. Structures and kinematics of the faults in the study region (Part 1). (a) Gneissic granite (Pt) overlying low-grade metamorphic rocks (Ptmj), abandoned military camp; (b) S-C foliations in gneissic granite indicating northwestward thrusting of the hanging wall, abandoned military camp; (c) Southeastward dipping thrust between gneissic granite (Pt) and low-grade metamorphic rocks (Ptmj), south to Deshengying; (d) S-C foliations in gneissic granite indicating northwestward thrusting of the hanging wall, Zhongdian-Houdian; (e) Gneissic granite (Pt) thrusting over the phyllite (Ptmj), northern boundary of Jiudi window; (f) Gneissic granite (Pt) thrusting over low-grade metamorphic rocks (Ptmj), southern boundary of Jiudi window; (g) Fault gouge zone between Archean marble (Ar) and gneissic granite (Pt), west to Wusutu; (h) Schistose tectonite developed on top of gneissic granite of the footwall, Erdaowa.

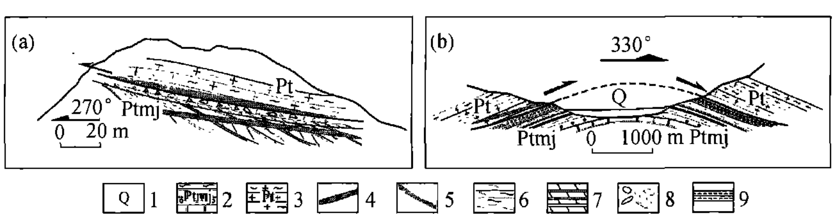

Fig. 3. Cross-section of Huangtuyaozi-Majiadian-Deshengying thrust. (a) Gneissic granite overlying low-grade metamorphic rocks, abandoned military camp; (b) Jiudi tectonic window. (1) Quaternary sediments; (2) low-grade metamorphic rocks of Proterozoic; (3) Gneissic granite of Proterozoic; (4) syn-deformational dyke; (5) retrograded metamorphic zone; (6) schistose tectonite; (7) cleaved low-grade metamorphic rocks; (8) Fault gouge zone; (9) strongly deformed black schistose tectonite.

South to Deshengying village, the fault plane dips to the southeast with a general dip angle of about 20° (Fig. 2(c)). The hanging wall is the Proterozoic gneissic granite in which the foliations dip N60°E with a dip angle of 50°. The footwall is phyllites interlayered by marble, in which developed close-spaced cleavages dipping S50°E with angles of about 30°. The cleavage attitudes also indicate a northwestward thrusting of the hanging wall.

A klippe controlled by the Huangtuyaozi-Majiadian-Deshengying thrust was found in the area near Majiadian and Houdian (the western part of Fig. 1). This klippe is composed of gneissic granite with mylonite developed at the base. The footwall is low-grade metamorphic rocks. The thrust can be seen around the klippe. On the southeastern side, the lineation in the basal mylonite of the klippe plunges S45° E with a plunge angle of 15°, and the foliation dips S60°E with a dip angle of 15°. The S-C foliations indicate a northwestward thrusting of the klippe (Fig. 2(d)). On the northwestern side, tectonic foliations developed in the marble of the footwall which dip S60°E with an angle of 20°. Meanwhile, brittle faults and striations also formed in this marble, and the striations plunge down the dip of the faults.

In addition to the klippes, the Huangtuyaozi-Majiadian-Deshengying thrust also formed some tectonic windows, among of them the Jiudi window east to Huanghuawopu is the biggest one with a north-south width of about 3 km (Figs. 1, 3(b)). The hanging wall of the window is composed of Proterozoic gneissic granite, while the footwall consists of low-grade slate and phyllite. Strongly deformed black schistose tectonite developed on top of the footwall (Fig. 2(e)). The fault confining the window takes a doming shape. On the northern boundary, the fault dips N30°W with a dip angle of 30°. A group of lineation plunging N40°W formed in granite of the hanging wall, while striations formed in the tectonites on top of the footwall which also plunge N40° W with an plunge angle of 25°. On the southern boundary, the fault dips southeastwards, the granite of the hanging wall was deformed and syn-deformation dykes intruded along the fault (Fig. 2(f)).

3.2 Wusutu-Huanghuawopu-Suletu thrust

Along this fault, the Archean gneiss and marble were thrusted northwestwards over the Proterozoic gneissic granite. In Huanghuawopu, foliations in the hanging wall dip gently southwards while those in the granite of the footwall dip northwards; the fault plane generally dips toward the south with a dip angle of 18°, and it has a 10 m-thick gouge zone in which the clasts are mainly marbles of the hanging wall. It is noticeable that there is a layer of very low-grade metamorphosed but strongly deformed sedimentary rocks on the fault plane.

West to Wusutu, this thrust dips N60°E with a dip angle of 42°; the Archean marble and the Proterozoic gneissic granite make the hanging wall and the footwall respectively. Along the fault plane formed a gouge zone (Fig. 2(g)) and intruded some potassic granite dikes. Tectonic foliations parallel to the fault plane formed in the gouge and the adjacent wall rocks, and on these foliations developed hot striations plunging S65°E with plunge angles of about 25°. The fault here is a lateral ramp of the thrust according the fault attitude and the kinematics.

The Wusutu-Huanghuawopu-Suletu thrust exposes another lateral ramp in Erdaowa, with Archean marble and Proterozoic gneissic granite as the hanging wall and footwall. A 2—3 m thick zone of schistose tectonite formed on top of the footwall and the schistosities dip N25°E with dip angles of about 40°. A group of striation plunging N65°W developed on the schistosities, and S-C foliations in tectonites indicates a northwestward movement of the hanging wall on this lateral ramp (Fig. 2(h)).

Like Huangtuyaozi-Majiadian-Deshengying thrust, this thrust also formed many tectonic windows and one example exposes in Nanquanzi (Fig. 1, 4(a)). The hanging wall of this window is silicated Archean marble, while the footwall is composed of low-grade metamorphic conglomerates. Pebbles of the conglomerates are marble, granite and some quartzite, and the cements are carbonaceous. The base of the hanging wall was strongly mylonitized, whereas the top conglomerates of the footwall were intensively foliated to form cleaves, phyllonite and breccias (Fig. 5(a)). The fault plane is parallel with the foliations of the hanging wall, but it sometimes takes the shape of corrugation (Fig. 5(b)).

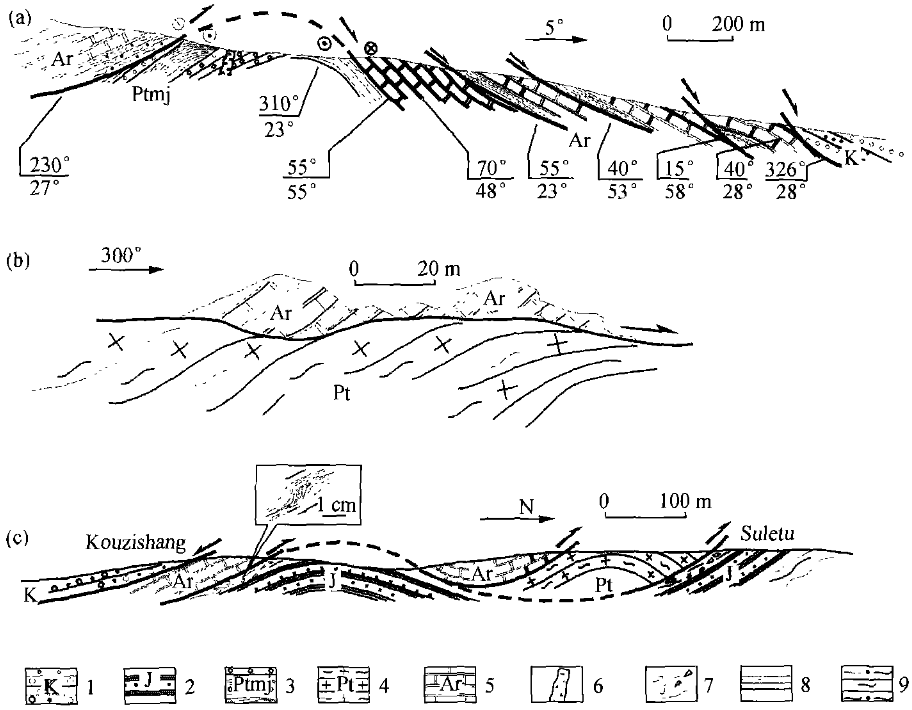

Fig. 4. Cross-sections of the Wusutu-Huanghuawopu-Suletu thrust. (a) The Nanquanzi tectonic window; (b) Archean marble clippes; (c) Kouzishang-Suletu section. (1) Cretaceous conglomerate; (2) Jurassic mauve sandstone and mudstone; (3) Proterozoic low-grade metamorphic rocks; (4) Proterozoic gneissic granite; (5) Archean marble; (6) porphyrite dykes; (7) gouge zone; (8) schistose tectonite; (9) mylonite at the base of hanging wall.

This window is prolonged and confined by two faults on its northern and southern boundaries. The northern boundary fault dips N55°E with a dip angle of 55°. Nearly horizontal striations formed on the fault surface and they plunge gently to S75°E. The southern fault dips S50°W with an angle of 27°; lineations plunging N65°E with angles of about 22° formed at base of the hanging wall. Small asymmetric folds adjacent to the fault plane indicate a northwestward movement of the hanging wall, indicating that this window is confined by two lateral ramps.

The Wusutu-Huanghuawopu-Suletu thrust also formed some klippes; the isolated marble peaks north to Huanghuawopu are the most typical examples (Fig. 4(b), 5(c)). These two klippes are composed of Archean marble in which the foliations dip S45°E with a dip angle of 70°. The footwall is gneissic granite and foliations in it dip N75°E with an angle of 75°. Toward the fault, the foliations in the footwall were dragged to be parallel to fault plane along which developed a gouge zone (Fig. 5(d)).

The Kouzishang-Suletu section shows excellently the structural characteristics of the Daqingshan thrusting system (Fig. 4(c)). This section includes two tectonic sheets and one autochthon. The two sheets are the metamorphic crystalline sheet and the gneissic granite sheet, while the autochthon consists of Jurassic sandstone and mudstone. In the southern part of the section, the Archean marble was thrusted directly over the Jurassic sandstone. The fault plane dips S15°W with a dip angle of 45°. The hanging wall is shattered and silicated marble and the footwall is slightly metamorphosed sandstone whose beddings dip S10°W with dip angles of about 30°. A thick gouge zone developed between the two walls in which drag structures and asymmetric porphyroclasts were formed. In the middle of this section, the Archean marble formed klippes overlying both Jurassic sandstone and Proterozoic gneissic granite, indicating an imbricate pattern of the thrusts. In northern part of the section, the hanging wall is Proterozoic gneissic granite with foliations dipping N10°W with a dip angle of 20°, and the footwall is mauve mudstone whose beddings dipping S50°W with an angle of 50°. The fault plane dips N30°W with a dip angle of 45°, along which developed a gouge zone of 20 cm (Fig.5(e)).

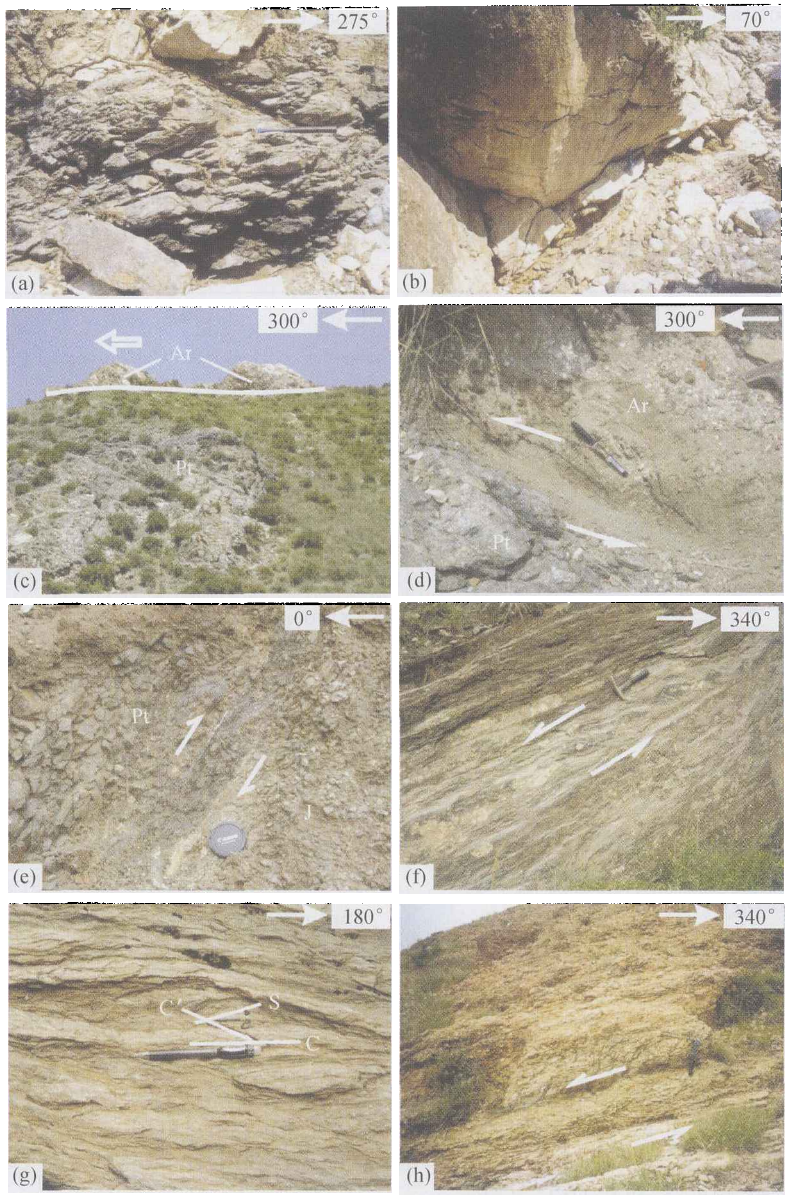

Fig. 5. Structures and kinematics of the faults in the study region (Part 2). (a) Schistose tectonite in Nanquanzi tectonic window; (b) corrugation structures in Nanquanzi tectonic window; (c) klippes of Archean marble (Ar) underlain by Proterozoic gneissic granite (Pt), north to Huanghuawopu; (d) gouge zone between the Archean marble (Ar) and Proterozoic gneissic granite (Pt), north to Huanghuawopu; (e) proterozoic gneissic granite (Pt) thrusted over the mauve mudstone of Jurassic (J), Suletu; (f) trains of mica-schist lenses in marble, Hongshankou; (g) synthetic extensional crenulations (C′) in Archean gneiss, parallel with main detachment fault, Hongshankou; (h) Daqingshan detachment fault in Hongshankou, the acute angle between the fault plane and the close-spaced cleavages in the footwall indicates a down-dip slide of the hanging wall.

4 Daqingshan detachment fault

Located in the southern part of the study region (Fig. 1), the Daqingshan detachment fault truncated the uppermost metamorphic crystalline sheet, and juxtaposed the Cretaceous red conglomerates directly over the Archean marble and gneiss. Because this fault has been fully reported[18], we only describe briefly two exposures in Halaqin and Hongshankou.

4.1 Halaqin section

The detachment fault plane exposed in Halaqin (Figs. 1, 6) dips S25°W with a dip angle of 37°. The hanging wall is Cretaceous red conglomerates, whereas the footwall is the Archean marble interlayered by biotite schist. Foliations in the footwall dip S65°E with dip angles of about 20° and excellent asymmetric porphyroclast systems formed in them.

In some localities, biotite-schist lenses in marble arrange in a train and indicate a southward sliding of the hanging wall (Fig. 5(f)). On the hanging wall, domino structures, brittle faults, and cleavages developed very well and all of them show the south-directed detachment.

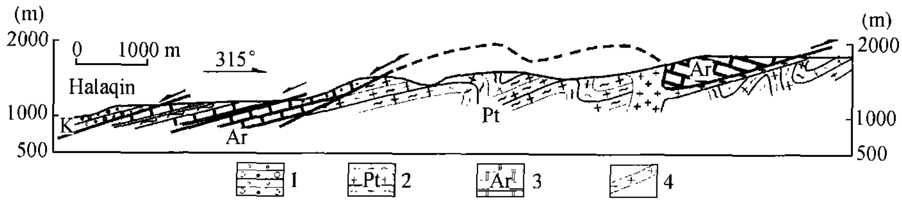

Fig. 6. Cross-section of Daqingshan detachment fault in Halaqin. (1) Cretaceous conglomerate; (2) Proterozoic gneissic granite; (3) Archean marble; (4) Yyn-deformational dyke.

4.2 Hongshankou

The fault plane dips S30°W with a dip angle of 25° in Hongshankou (Fig. 1). The hanging wall is Cretaceous red conglomerates, the footwall is the Archean marble and gneiss, and a gouge zone developed in between. The normal faulting indicators include: synthetic extensional crenulations (C′) in gneiss—here the C foliations dip S20°W with dip angles of about 30° and make an angle of about 30° with C′ foliations (Fig. 5(g)); acute angles between fault plane and the cleavages in the footwall indicate a down sliding of the hanging wall (Fig. 5(h)).

5 Tectonic chronology

In earlier days, Wang[22] and Sun[23] speculated that the Daqingshan thrusting system formed in Cretaceous, whereas Wang and Yang[24] thought it formed in late Jurassic. The study of Zheng et al.[11] in Dalanqi area (Fig. 1) obtained the minimum ages of 119 ± 2 Ma for the thrusting by zircon U/Pb dating on the footwall granite. Recently, Liu et al.[21] carried out conventional and laser $^{40}Ar/^{39}Ar$ dating on the syn-deformational biotite and muscovite in the thrusts, and obtained an isochron of 121.6 ± 1.6 Ma, providing the envidence for that Daqingshan thrusting system was mainly formed in early Cretaceous.

Davis et al.[18] believed that the Daqingshan detachment fault formed during the period from 125 Ma to 121 Ma, by dating the crystallization ages of granite related to the fault and $^{40}Ar/^{39}Ar$ ages of the fault-related mylonite. In addition, the hanging wall of the detachment fault is composed of red conglomerates. These rocks contact the high-grade metamorphic rocks with the detachment fault, and the base of the conglomerates was deformed by the fault. However, the distribution of the conglomerates is strictly constrained by the detachment fault, and the clasts and pebbles in the conglomerates are mainly marble and gneiss. Thus the conglomerates are syn-detachment sediments and these rocks belong definitely to the lower Cretaceous strata[25], and therefore, the extension happened in early Cretaceous. It can be seen that, in the Daqingshan orogen, the thrusting and the detachment are basically simultaneous.

6 Discussion and conclusions

In Mesozoic, North China plate experienced not only strong contraction, but also intensive extension[7], and both thrusting system and metamorphic core complexes formed in Daqingshan. As for the formation of the metamorphic core complexes, the orogeny → crustal thickening → collapse extension model has been chosen as the preferred one[18,26]. However, our field observations showed that both thrusting and extension in the Daqingshan orogen formed possibly at the same time, and the structural pattern and formation of the Daqingshan orogen have the following characteristics.

(1) In the study region, the old basement rocks making up the Hohhot metamorphic core complex were thrusted over the lower-grade metamorphic rocks, and the thrusting structure and kinematics are obvious. This crystalline basement formed a sheet with a thickness of only about 2 km in the Kouzishang-Suletu cross-section, and this sheet was thrusted directly over the Jurassic sandstone along the Wusutu-Huanghuawopu-Suletu thrust (Fig. 4(c)). In Nanquanzi, this sheet was found to be thrusted over phyllite and meta-conglomerates of Proterozoic. This shows that the originally defined Hohhot metamorphic core complex may be a tectonic sheet belonging to the thrusting system; this sheet is confined by the Wusutu-Huanghuawopu-Suletu thrust at base and

truncated by the Daqingshan detachment fault on top (Fig. 7(a)).

(2) Temporally, the existing data show that the thrusting happened at nearly the same time as the extension in Daqingshan.

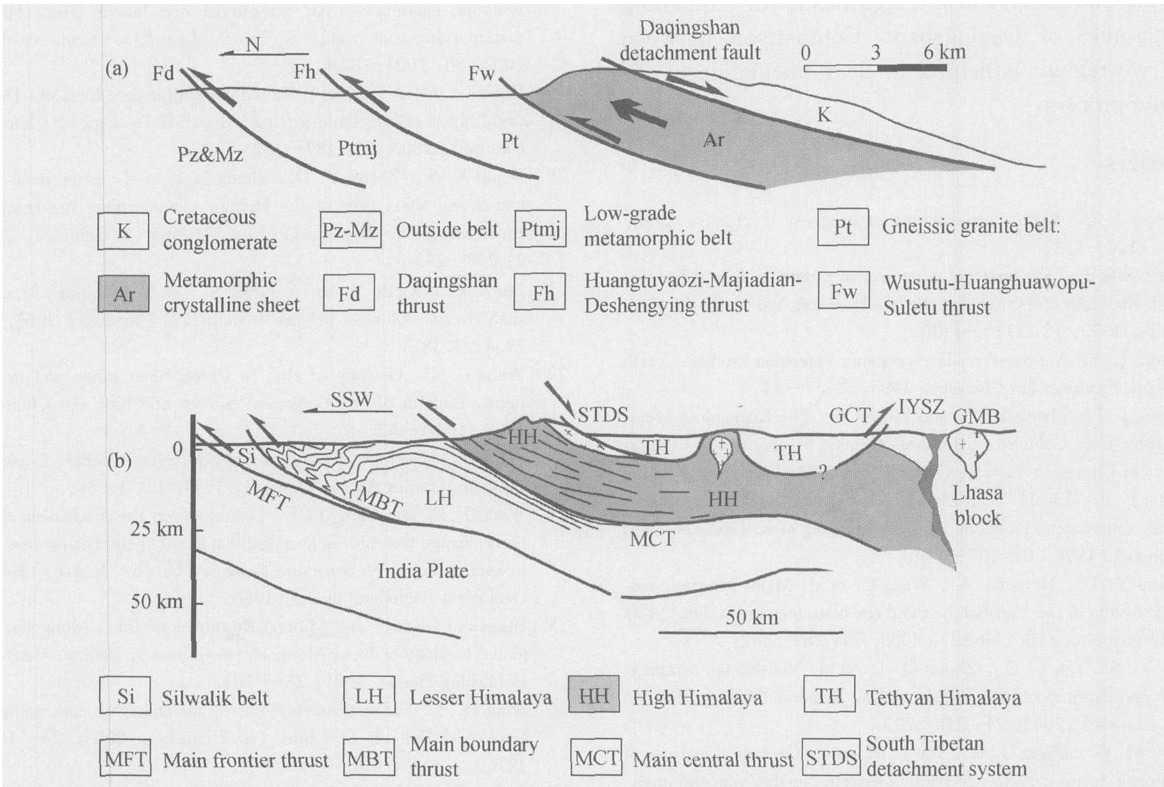

Fig. 7. Comparison in structural patterns between Daqingshan and Himalaya. (a) Sketch section of the Daqingshan thrsting system; (b) sketch section of Himalaya (after LeFort, 1996[27]).

The above two characteristics make the Daqingshan orogen comparable to the Himalayan orogan. The Himalayan orogen is composed of several south-directed thrusts, and a north-directed sliding fault—the south Tibetan detachment system (STDS) (Fig. 7(b)). Successively from south to north, these thrusts are main frontier thrust (MFT), main boundary thrust (MBT) and main central thrust (MCT); separated by the thrusts are the belts of Siwalik, Lesser Himalaya, High Himalaya, respectively. Similar to the Daqingshan, the uppermost sheet of the Himalayan thrusting system, the High Himalaya, is also a high-grade crystalline sheet with a thrust (MCT) at the base and a detachment fault (SDTS) on top. Moreover, activities of the SDTS and MCT are simultaneous, both of them began to deform about 24 Ma ago[28,29].

Based on the simultaneous MCT and STDS, many models have been proposed, such as gravitational collapse[30,31], wedge extrusion[32,33] and passive roof fault[34]. It is because of the simultaneousness of MCT and STDS that no one takes the high Himalaya as a metamorphic core complex. Although the mechanism of the fault on top of High Himalaya has not been explained well, our recent study showed that the kinematics of the STDS was north-directed sliding, at least at its later stage[35]. Therefore, the formation mechanism for the structural pattern of the Daqingshan orogen seems to be similar to that of the Himalayan orogen.

In summary, three large-scale thrusts formed in the Daqingshan orogen along the range, these thrusts separated the orogen into four tectonic belts (or tectonic sheets), and these thrusts and sheets formed a typical thrusting system. The southernmost metamorphic crystalline sheet is the originally defined Hohhot metamorphic core complex, which may be a sheet constituting the uppermost tectonic unit of the thrusting system. Chronological data show that the main thrusting in Daqingshan happened at the same time as the detachment faulting, which means that contraction and extension in this region occurred simultaneously. The structural pattern of the Daqingshan orogen is similar to that of the Himalayan orogen, and the Himalayan models with simultaneous thrusting and extension are significant for explaining the tectonics of Daqingshan. Comparison between these two regions is helpful to clear elucidation of the orogenic process.

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