十一、羊八井－当雄活动断裂与地震遗迹

羊八井－当雄活动断裂也称念青唐古拉山东南麓活动断裂，总体呈北东走向，局部呈近东西走向，主体分布于盆地西北部，部分分布于盆地内部和盆地东缘；第四纪发生过强烈活动，控制羊八井－当雄高温地热、温泉和地震的空间分布（吴中海等，2004；Wu Zhonghai et al., 2004）。羊八井－当雄盆西边界活动断裂呈锯齿状断续延伸，主要由斜列分布的正断层组成，局部断裂产状变化部位具有显著的左旋走滑分量；错动不同时代和不同成因的沉积地层，形成线性分布的高大断层三角面、断层崖、断层陡坎、悬谷等构造地貌，发育地震陡坎、地震破裂、地震鼓包、堰塞塘、拉分盆地等地震遗迹。羊八井－当雄盆西边界断裂第四纪平均垂直活动速率为 1.1±0.3mm/a，全新世平均垂直活动速率为 1.4±0.6mm/a，局部达 3-5mm/a。在宁中盆地、拉多岗盆地、羊八井盆地的内部和东部边界，发育北东向和北西向次级活动断层。

沿羊八井－当雄盆西边界活动断裂，1411 年发生过 8 级强烈地震，震中位于羊八井盆地西南部，在尼木、吉达果、羊八井、宁中、当雄等盆地的西北边界形成多级地震陡坎（吴章明等，1992）；1952 年发生的九子拉 7.5 级地震在当雄盆北边界断裂形成显著地震陡坎。在羊八井－当雄盆西边界活动断裂多数地点，观察到晚更新世－全新世多期古地震活动遗迹，包括多级地震陡坎、多期地震破裂、多期地震楔与地震鼓包、拉分盆地。根据地震遗迹观测资料，沿羊八井－当雄盆西边界活动断裂，全新世至少发生 4 次古地震事件，估算全新世期 7.5-8 级古地震的平均复发周期为 2300±700a。

PART 11 DAMXUNG-YANGBAJAIN ACTIVE FAULT SYSTEM AND ITS HOLOCENE EARTHQUAKE RELICS

The Damxung-Yangbajain active fault system is also named as southeast Piedmont normal fault system of Nyainqentanglha Mts. It generally trends in northeast direction and shows E-W trending in some segments in north of Damxung basin, controlling epicenters of earthquakes, seismic relics and high-temperature thermal fields where cluster of hotsprings and sinters formed (Wu et al., 2004). Damxung-Yangbajain active fault system is consisted of normal faults in en-echelon pattern in northwest boundary of Damxung-Yangbajain graben characterized by fault scarps, fault cliffs, stream offsets and seismic relics as seismic scarps, seismic fractures, pressure ridges, sag ponds and pull-apart basins formed in Quaternary. The average vertical slip rate is estimated as 1.4±0.6mm/a in Holocene in general and 3~5mm/a at some localities. Some minor faults of NE and NW trending formed in Ningzhong, Ladaogang and Yangbajain basins, controlling evolution of geothermal field and distribution of high temperature hotsprings.

Ms 8.0 Yangbajain earthquake occurred in 1411 with epicenter in west Yangbajain basin, formed seismic scarps and seismic fractures along west boundary faults of Jiadaguo depression and Yangbajain, Ningzhong and Damxung basins. And Ms 7.5 Jiuzila earthquake occurred in 1952 formed seismic fractures along north boundary fault of Damxung basin. In fact seismic activity is so intense that at least 4 earthquakes of Ms 7.5-8.0 occurred in Holocene with seismic interval time of 2300 ± 700a, formed widespread seismic relics in southeast piedmonts of the Nyainqentanglha Mts. along northwest boundary fault of Damxung-Yangbajain graben.

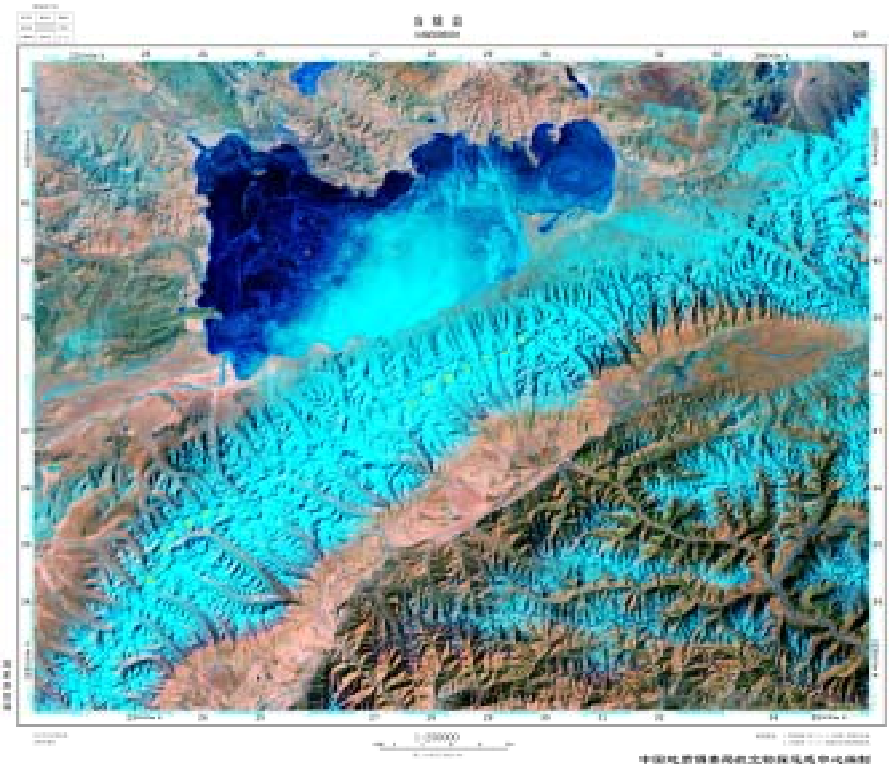


图 93 当雄幅 ETM 遥感影像图

Fig.93 ETM image of Damxung region in south Tibetan Plateau

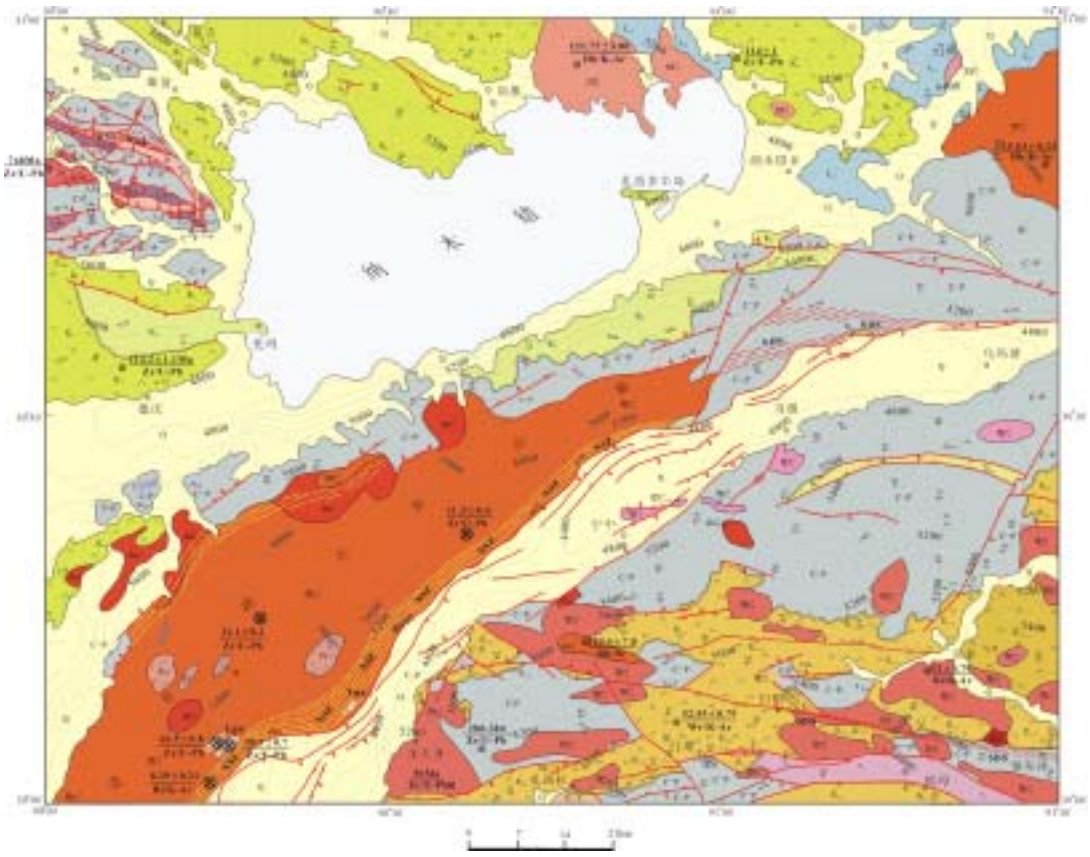


图 94 当雄幅构造地貌图

当雄幅构造地貌图地质构造内容来自于 2003 年提交的当雄幅 1:25 万地质图及区域地质调查报告；等值线表示山顶面及盆地面的海拔高度（m），反映地势变化趋势。Q-第四系；E_{1+2}-古新统与始新统；K_2-上白垩统；K_1-下白垩统；J_{2-3}-中上白垩统；C-P-石炭系—二叠系；D-泥盆系；Pt-元古代变质岩；J_2op-中侏罗统蛇绿岩；γ_5^2-侏罗纪二云母花岗岩；γ_5^3-白垩纪花岗岩；δo_5^3-白垩纪石英闪长岩；$\eta\gamma_6^1$-古近纪二长花岗岩；$\eta\gamma_6^3$-中新世二长花岗岩；NSZ-念青唐古拉伸展型韧性剪切带；NDS-当雄北侧片理化带；SDS-当雄东南侧领布冲压扭性韧性剪切带；WNS-纳木错西岸逆冲型韧性剪切带；Lgn-冷青拉片麻岩；Ygn-羊八井片麻岩。52.55±0.79/Zr/U-Pb-同位素年龄（Ma）/测年矿物/测年方法；Zr-锆石，Bi-黑云母，Wr-全岩，Hb-角闪石；U-Pb-铀—铅同位素测年，K-Ar-钾—氩同位素测年，Rb-Sr-铷—锶等值线测年。

Fig.94 Tectonic map of Damxung region in south Tibetan Plateau based on geological mapping at scale 1:250000 by Wu et al. (2003). Explanation: contours represent elevation (m) of summit and basin surfaces indicating geomorphic features created by neotectonic movement. Q-Quaternary deposits; E_{1+2}-Eocene-Oligocene volcanic-sedimentary strata; K_2-Upper Cretaceous strata; K_1-Lower Cretaceous strata; J_{2-3}-Middle-Upper Jurassic strata; C-P-Carboniferous-Permian stratigraphic system; D-Devonian limestone and sandstone; Pt-Proterozoic metamorphic rocks; J_2op-Middle Jurassic ophiolite; γ_5^2-Jurassic granite; γ_5^3-Cretaceous granite; δo_5^3-Cretaceous quartz diorite; $\eta\gamma_6^1$-Early Tertiary granite; $\eta\gamma_6^3$-Miocene granite; NSZ-Nyainqentanglha shear zone; NDS-north Damxung shear zone; SDS-Linbuchong shear zone in south of Damxung; WNS-west Namco shear zone; Lgn-Lengqingla gneiss; Ygn-Yangbajain gneiss; and 52.55±0.79/Zr/U-Pb represents isotopic ages(Ma)/mineral for dating/dating method with Zr-zircon, Bi-biotite, Wr-whole rock and Hb-hornblende.

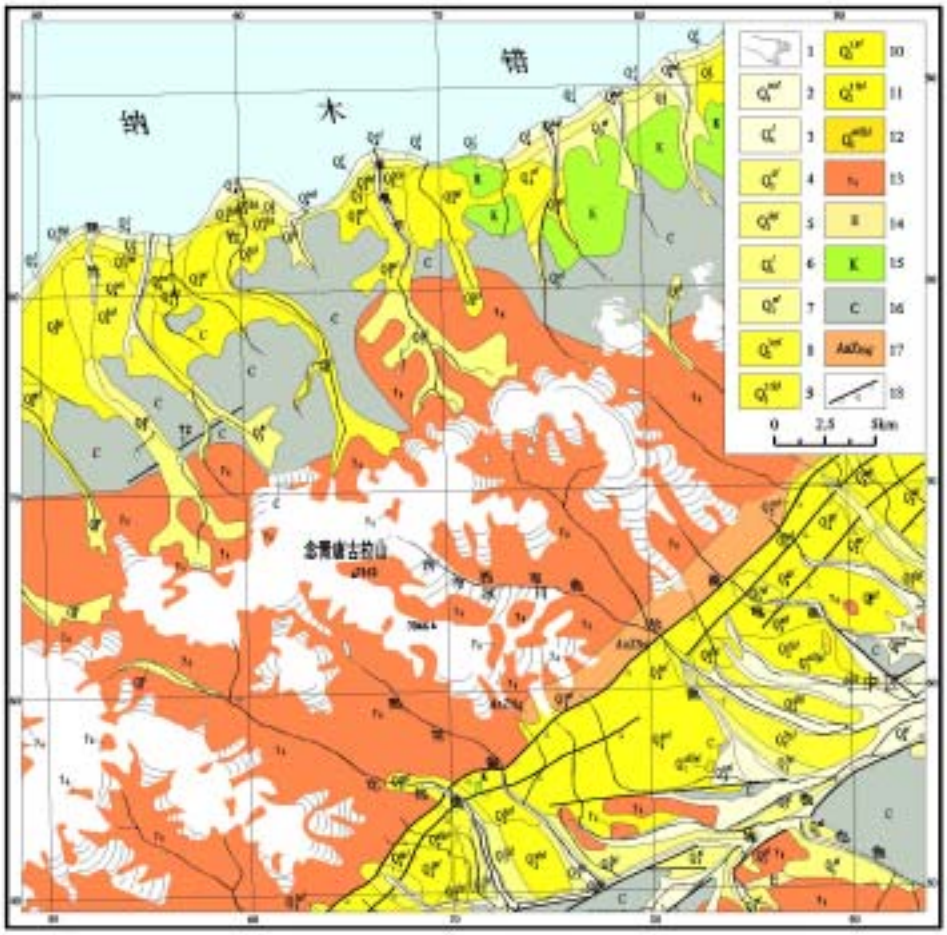


图 95 念青唐古拉地区第四纪地质图

1-现代冰川；2-全新统冲洪积物；3-全新统湖积物；4-上更新统拉曲冰期冰碛；5-上更新统拉曲冰期冰水沉积；6-上更新统湖积物；7-上更新统洪积物；8-上中更新统爬然冰期冰碛；9-上中更新统爬然冰期冰水沉积；10-下中更新统宁中冰期冰碛；11-下中更新统宁中冰期冰水沉积；12-下更新统河流或冰水沉积；13-喜马拉雅期花岗岩；14-始新统； 15-白垩系；16-石炭系；17-角闪岩相变质岩；18-断层

Fig.95 Quaternary geological map of Nyainqentanglha area. Explanation: 1-present-day glacial; 2-Holocene alluvial and fluvial deposits; 3-Holocene lacustrine deposits; 4-Late Pleistocene moraine of Laqu glacia-stage; 5-Late Pleistocene glacio-fluvial deposits of Laqu glacia-stage; 6-Late Pleistocene lacustrine deposits; 7-Late Pleistocene fluvial deposit; 8-late Middle Pleistocene moraine of Palen glacia-stage; 9-late Middle Pleistocene glacio-fluvial deposits of Palen glacia-stage; 10-early Middle Pleistocene moraine of Ningzhong glacia-stage; 11-early Middle Pleistocene glacio-fluvial deposits of Ningzhong glacia-stage; 12-Early Pleistocene alluvial or glacio-fluvial deposits; 13-Cenozoic grante; 14-Eocene; 15-Cretaceous; 16-Carboniferous; 17-metamorphic rocks of amphibolite faces; 18-fault.

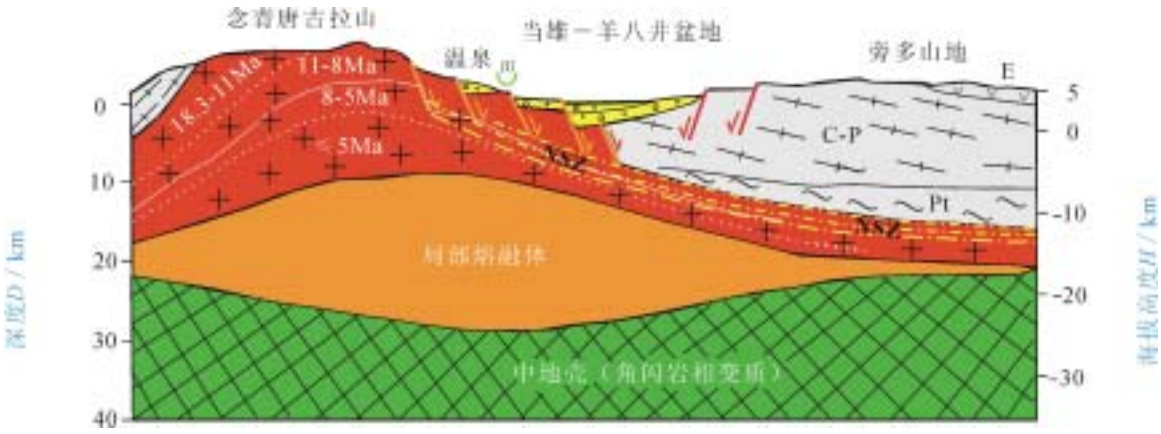


图 96 羊八井—当雄盆地的地壳结构与构造样式图

Fig. 96 Cross-section of crust across the Nyainqentanglha Mts. and Damxung-Yangbajain graben according to geological mapping by Wu et al. (2003) and INDEPTH-II seismic reflection, indicating extensional tectonic style of Damxung-Yangbajain graben

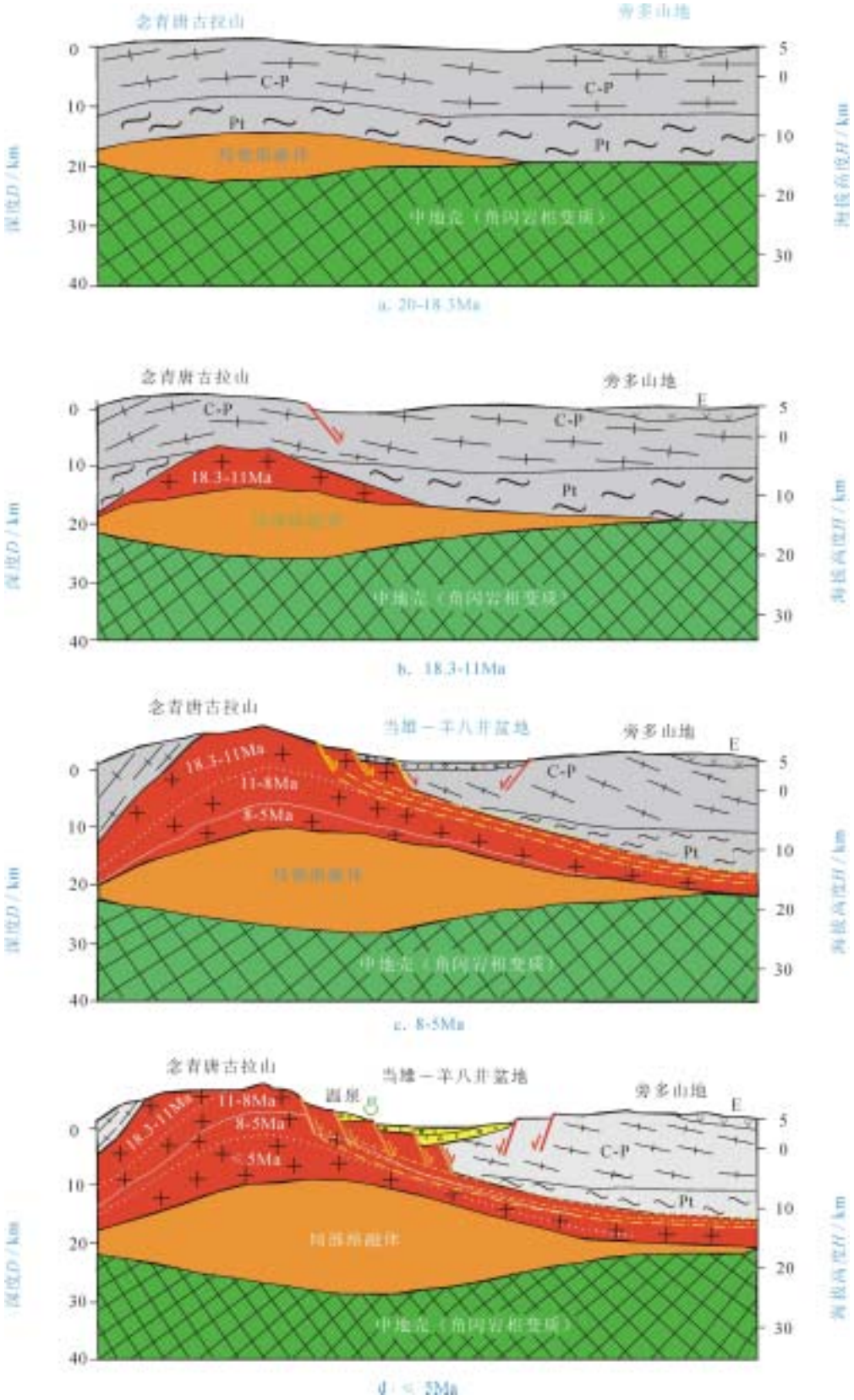


图 97 羊八井—当雄盆地构造地貌演化图

（念青唐古拉山花岗岩年龄资料据刘琦胜等，2003；Liu et al., 2004）

Fig.97 Sketch map showing evolution of Damxung-Yangbajain graben and Nyainqentanglha Mts. since Miocene and the ages of Nyainqentanglha granite came from U-Pb isotopic dating of zircon by SHRIMP (Liu et al., 2003,

2004)



图 98 念青唐古拉花岗岩与现代山岳冰川地貌

（镜头向西，摄于羊八井西侧古仁曲沟头）

Fig.98 View westward at present-day mountainous glacial overlying Miocene Nyainqentanglha granite in west of Yangbajain basin



图 99 念青唐古拉花岗岩与糜棱岩接触关系

上部为中新世晚期花岗质粗糜棱岩，指示上盘下滑运动方向，下部为中新世早中期念青唐古拉黑云母二长花岗岩；镜头向北东，摄于羊八井西侧古仁曲。

Fig.99 View northeastward at contact between mylonite and Miocene granite in Gurenqu valley



图 100 念青唐古拉花岗岩顶部韧性剪切糜棱岩面理

（花岗质糜棱岩片理倾角为 25°-30°；镜头向北东，摄于羊八井西侧古仁曲）

Fig.100 View northeastward at mylonite schist of ductile sheared granite in Gurenqu valley

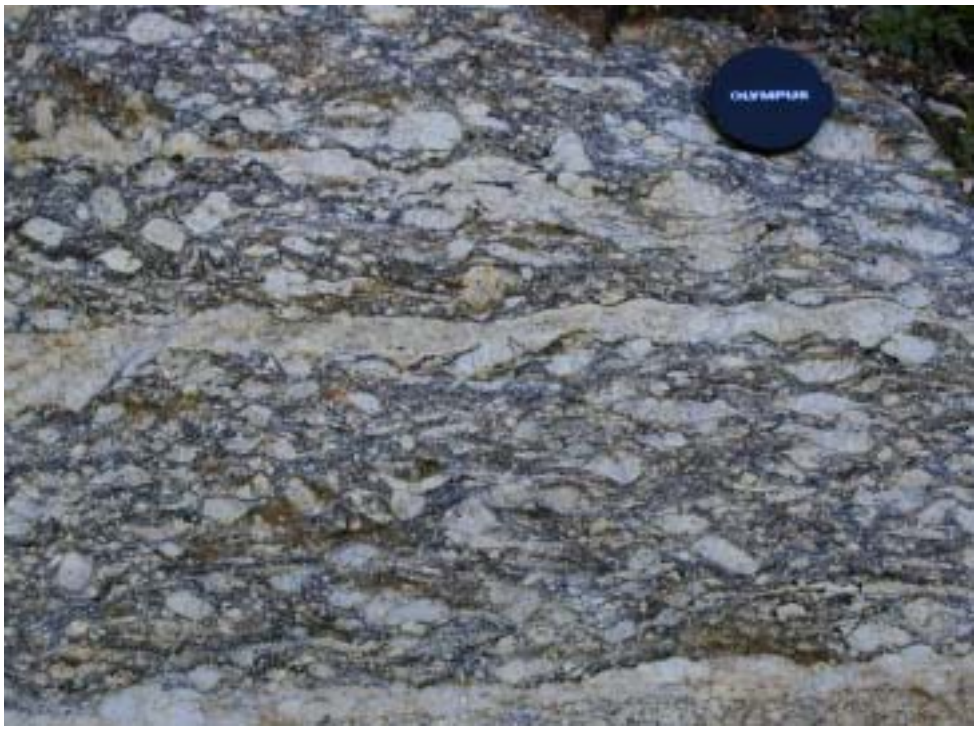


图 101 念青唐古拉山东部韧性剪切带糜棱岩

（糜棱岩发育眼球状构造，指示相对运动方向；镜头向北东，摄于羊八井西侧古仁曲）

Fig.101 Near view northeastward at lens structure of mylonite of ductile sheared Miocene granite in Gurenqu

valley



图 102 念青唐古拉山东部韧性剪切带花岗质糜棱岩

（花岗质糜棱岩发育眼球状构造，指示上盘向南东方向运动；镜头向北东，摄于羊八井西侧古仁曲沟口）

Fig.102 View northeastward at foliation and lens structure of granitic mylonite of SNS in west of Yangbajain graben



图 103 念青唐古拉山东麓晚期高角度正断层切割糜棱岩面理

（镜头向南西，摄于羊八井西侧古仁曲沟口）

Fig.103 View southwestward at normal faults cutting mylonite foliations of NSZ formed in southeast Nyainqentanglha granite in west boundary of Yangbajain basin



图 104 当雄盆地西北边界断裂切割中更新世晚期冰碛形成阶地状断裂陡坎

（镜头方向 230°，摄于当雄盆地西北吉东棍巴西侧）

Fig.104 View southwestward at normal boundary fault cutting late Middle Pleistocene moraine in northwest of Damxung basin



图 105 当雄盆地东端边界断裂切割晚更新世沉积形成断层崖

（陡坎显示 1952 年 7.5 级地震破裂位置，镜头向北西）

Fig.105 View northwestward at seismic fracture of Ms 7.5 Jiuzila earthquake occurred in 1952 along north

boundary fault of Damxung basin



图 106 当雄盆地东端边界断裂 1952 年 7.5 级地震陡坎

（断裂切割现代坡积物，形成 1.7m 的自由面；镜头方向 80°，摄于年波西侧）

Fig.106 View eastward at seismic scarp of Ms 7.5 Jiuzila earthquake occurred in 1952 in east section of north boundary fault of Damxung basin



图 107 当雄盆地东端边界山前断裂斜滑形成的擦痕和阶步

（镜头向北）

Fig.107 View northward at striation and slickenside of north boundary fault of Damxung basin indicating oblique slip



图 108 当雄盆地东北乌玛塘北侧断裂左旋走滑形成地震陡坎与断塞塘

（镜头方向 70°，摄于央麦岗）

Fig.108 View east northeastward at seismic scarps and sag pond along north boundary fault of Wumatang depression, east part of Damxung basin



图 109 当雄盆北边界断裂 1411 年 8 级地震陡坎

（镜头向北，摄于当雄电站北侧）

Fig.109 View northward at multi-level seismic scarps of Ms 8.0 Yangbajain earthquake occurred in 1411 in north of Damxung Power Station



图 110 当雄盆北断裂陡坎与剖面位置

（断裂切割晚更新世冲积扇，镜头向西，摄于那根拉山口）

Fig.110 View westward at north boundary fault cutting Late Pleistocene alluvial fan of Damxung basin



图 111 当雄盆北主边界断裂切割中更新世晚期冰碛物在那根拉山口形成古地震楔

（断裂切割晚更新世冲积扇，形成地震楔；镜头向北，摄于那根拉山口）

Fig.111 View northward at seismic wedge formed in north boundary fault cutting Late Pleistocene moraine of Damxung basin



图 112 当雄盆北主边界断裂古地震楔

（断裂切割晚更新世冲积扇，地震后崩积充填于地震破裂，形成古地震楔；镜头向北西，摄于那根拉山口）

Fig.112 Near view northwestward at seismic wedge consisted pebbles filled in seismic fracture along boundary fault in north of Damxung basin



图 113 当雄盆北断裂左旋走滑形成地震鼓包与小型拉分盆地

（镜头向南西，摄于当雄机场北侧）

Fig.113 View southwestward at seismic fracture of sinistral slip, pressure ridges scattered in en-echelon pattern and pull-apart basin in north of Damxung



图 114 当雄盆地东部北边界断裂左旋走滑与反向地震陡坎

（镜头向西，摄于乌玛塘北侧肯弄）

Fig.114 View westward at seismic fracture of sinistral slip, seismic scarps and pull-apart basin in north boundary

of Wumatang depression, east part of Damxung basin



图 115 宁中盆地中更新世冰碛台地南侧亚运圣火采集地点

（镜头向北）

Fig.115 View northward at Middle Pleistocene moraine terrace and Memorial for 11th Asian Olympic Game



图 116 宁中盆地东北侧边界断裂躺兵错拉分盆地

（镜头向北东）

Fig.116 View northeastward at Tangbingco Lake in pull-apart basin in north boundary of Ningzhong basin



图 117 宁中盆地东北躺兵错西侧边界断裂切割中更新世冰碛台地形成堰塞塘

（镜头方向 230°）

Fig.117 View southwestward at sag pond and seismic depressions along boundary fault in west of Tangbingco Lake, northeast of Ningzhong basin



图 118 宁中盆地西北拉曲沟口边界断裂切割全新世冰水台地形成崩积楔

（镜头方向 30°）

Fig.118 View north northeastward at boundary fault cutting Holocene glacio-fluvial fan in northwest of Ningzhong basin



图 119 宁中盆地北东向与北西向活动断裂复合部位发育喷泉

（镜头向北东）

Fig.119 View northeastward at out-flowing spring-water in Ningzhong geothermal field formed in compounding position of active faults trending in NW and NE orientations



图 120 宁中盆地北西向断裂切割泉华台地

（镜头向南东）

Fig.120 View southeastward at NW-trending fault cutting Holocene sinter in Ningzhong geothermal field



图 121 宁中盆地北西向断裂切割泉华台地形成片理化带

（镜头向北西）

Fig.121 View northwestward at cleavage of NW-trending fault cutting Holocene sinter in Ningzhong geothermal field



图 122 拉多岗盆地北东向活动断层切割错断中更新世冰水沉积

（镜头向北东）

Fig.122 View northeastward at NE-trending active fault cutting Middle Pleistocene glacio-fluvial deposits in Laduogang geothermal field in northeast part of Yangbajain basin



图 123 古仁曲沟头 1411 年 8 级地震引发雪崩消融后遗留的冰川沉积

（镜头向北西）

Fig.123 View northwestward at deposits left by thawed avalanche caused by Ms 8.0 Yangbajain earthquake in 1411 in southeast end of Gurenqu valley



图 124 羊八井盆西古仁曲横穿念青唐古拉山脉的峡谷地貌

（镜头向南东）

Fig.124 View southeastward at NW-trending Gurenqu valley across Nyainqentanglha Mts. in west of Yangbajain basin

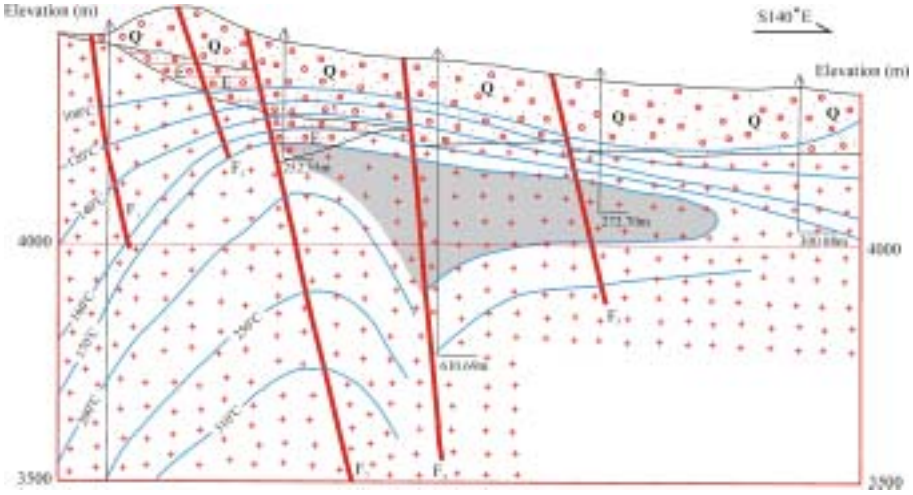


图 125 羊八井地热田钻探剖面与地温等值线图

（据梁廷玉、多吉等，1995，略加补充改编）

Fig.125 Cross section of Yangbajain geothermal field with blue lines indicating isobath of temperature and shadow marking high-temperature thermal reservoir based on drilling data from Liang and Duoji et al., 1995



图 126 羊八井盆北边界断裂左阶斜列的断层陡嵌

（镜头向北东）

Fig.126 View northeastward at left-stepped en-echelon fault scarps along normal fault in northwest boundary of Yangbajain basin



图 127 羊八井西侧那夙果沿边界断裂发育的 1411 年 8 级地震陡坎切割现代冲积扇

（镜头向北西）

Fig.127 View northwestward at seismic scarp of Ms 8.0 Yangbajain earthquake cutting present-day alluvial fan



图 128 羊八井盆北边界断裂切割全新世冰水扇形成陡坎地貌

（镜头向北）

Fig.128 View northward at normal fault cutting Holocene deposits in north boundary of Yangbajain basin



图 129 羊八井盆地东北边界断裂切割中更新世晚期冰川侧碛形成陡坎地貌

（镜头向北）

Fig. 129 View northward at normal fault cliffs vertically slipped late Middle Pleistocene moraine in north boundary of Yangbajain basin



图 130 羊八井盆地西北嘎罗棍巴边界断裂切割基岩形成陡崖和镜面

（镜头向西）

Fig.130 View westward at normal fault cliffs and slikenside in northwest boundary of Yangbajain basin



图 131 羊八井盆地西北边界断裂切割中更新世冰碛物形成擦痕面

（镜头向北东）

Fig.131 View northeastward at normal faulted Middle Pleistocene moraine in northwest boundary of Yangbajain basin



图 132 羊八井盆东北西向断裂切割晚更新世沉积

（镜头向南东）

Fig.132 View southeastward at east boundary fault of Yangbajain basin cutting Late Pleistocene deposits



图 133 军马场盆西边界断裂陡坎

（镜头向北西）

Fig.133 View northwestward at normal fault scarp in west boundary of Junmachang depression, south part of Yangbajain basin



图 134 军马场盆西多级断裂陡坎

（镜头向北）

Fig.134 View northward at multi-level normal fault scarps in west boundary of Junmachang depression, south part of Yangbajain basin



图 135 军马场盆西边界断裂左旋切割错断中更新世晚期冰水台地

（帐篷为野外宿营地，镜头向北东）

Fig.135 View northeastward at normal fault with sinistral slip of Middle Pleistocene glacio-fluvial deposits in west boundary of Junmachang depression



图 136 军马场盆西边界沿断裂破碎带发育的现代滑塌

（镜头向西）

Fig.136 View westward at rock sliding along boundary fault in west of Junmachang depression



图 137 羊八井南侧吉达果盆北边界断裂陡坎与王曰错断陷湖盆

（镜头向南西西）

Fig.137 View west southwestward at geomorphic features and pull-apart basin along active fault in north boundary of Jidaguo depression as south part of Yangbajain basin



图 138 羊八井南侧吉达果盆北边界断裂陡坎与冰川悬谷地貌

（镜头向西）

Fig.138 View westward at normal fault cliffs and hanging valley in north boundary of Jidaguo depression as part of Yangbajain basin



图 139 羊八井南侧吉达果盆北边界断裂 1411 年 8 级地震破裂错断现代河漫滩 4-5m
（镜头向北东）

Fig.139 View northeastward at 4-5m vertical slip of present-day alluvial fan caused by Ms 8.0 Yangbajain earthquake occurred in 1411 along north boundary fault of Jidaguo depression



图 140 羊八井南侧吉达果盆地西北边界断裂 1411 年 8 级地震破裂
（镜头向西，摄于夹多乡西南侧）

Fig.140 View westward at seismic fracture of Ms 8.0 Yangbajain earthquake occurred in 1411 with proportional sinistral slip of streams along northwest boundary fault of Jidaguo depression



图 141 羊八井南侧吉达果盆地边界断裂 1411 年 8 级地震破裂错断现代河床

（镜头向西）

Fig.141 View westward at seismic fracture of Ms 8.0 Yangbajain earthquake cutting present stream along west normal fault of Jidaguo depression