

countries to mineral resources, especially to the difference of mining activities and other industry, so if we can, in term of different developing conditions of different countries, manage the 21st century's mining industry to incline to developing states of "post-industry", trying to make it realize the survival of the fittest and sustainable development — obviously, it is also an important project expecting to be discussed. In this paper, on the basis of the general discussion for developing state of the 21st century's mining industry, the characteristics of mining activities and its natural property, the author proposes a modeling of geological exploration for sustainable development of mining industry and decision-making system for mining activity, as well as the new "recognized intellect" for sustainable development of very shortage copper deposits.

**Key words:** post-industry; new economy; new recognized intellect; double control theory and reasonable zone; derivative processes; tectogenesis.

\*\*\*\*\*

## 喜马拉雅造山带中段核部杂岩中基性麻粒岩的发现及构造意义

李德威, 廖群安, 袁晏明, 易顺华

(中国地质大学地球科学学院, 湖北武汉 430074)

举世瞩目的喜马拉雅造山带隆升幅度大、剥蚀作用强、构造活动新, 至今为止, 只是在该造山带东西 2 个构造结(帕米尔地区和南巴迦瓦地区)中发现了下地壳深变质岩. 近期笔者在 1:25 万定结幅区域地质调查中首次发现喜马拉雅构造带中段曲当—康几一带的前寒武系聂拉木岩群中具有强烈塑性变形和多期退变质的基性麻粒岩, 这对于研究喜马拉雅造山带的地壳物质组成、下地壳流变状态、陆内造山过程和构造隆升机制等均具有十分重要的意义.

位于喜马拉雅造山带核部的聂拉木岩群基底变质杂岩主要由黑云石英片岩、石英片岩、黑云母片岩、石英岩、大理岩、片麻岩、混合岩、混合片麻岩、石榴角闪岩组成. 在其下部还有灰色片麻岩和原地一半原地片麻状—眼球状花岗岩. 此外, 常见喜马拉雅期 S 型花岗岩的侵入. 变质杂岩及其侵入其中的淡色花岗岩与上覆沉积盖层之间呈大规模的拆离断层接触, 构成喜马拉雅变质核杂岩, 形成地壳尺度的伸展构造体系.

基性麻粒岩大多数呈透镜体、团块状、似层状产于片麻岩和石英岩中, 与围岩呈构造接触关系, 由糜棱面理和构造片理构成局部化强应变带. 在区域上为大型的低角度韧性剪切带, 韧性剪切带大多为正

断式, 显示伸展构造特征, 有些麻粒岩也卷入韧性剪切, 形成剪切透镜体, 局部出现片理化现象和流变褶皱. 在片麻状花岗岩和片麻状英云闪长岩中也含有基性麻粒岩包体, 出现退变质反应结构, 但麻粒岩相的残留矿物(如紫苏辉石)发育.

基性麻粒岩具斑状变晶结构, 石榴石颗粒较粗, 粒径一般为 4~6 mm. 麻粒岩中后成合晶结构和冠状反应边结构十分发育, 可识别三期变质矿物组合: 早期的石榴石和相对富铝的单斜辉石具高压变质特征, 很可能为 B 型榴辉岩的残余, 初步认为它形成于喜马拉雅造山带根部深层高压变质环境. 一个普遍发育而且十分重要的现象是石榴石核部几乎完全被后成合晶(Pl+Opx+Cpx)所取代, 白色的冠状反应边主要由斜长石组成, 还有少量的角闪石和普通辉石; 中期的麻粒岩相组合为 Opx+Cpx+Pl±Sp, 其中 Opx 和 Pl 为石榴石的后成合晶, 构成冠状体假象, 在早期单斜辉石边缘形成新的单斜辉石反应边, 其中单斜辉石均为富钙的透辉石, 斜方辉石成分变化大, 主要为紫苏辉石, 其次为顽火辉石, 矿物成分显示低压麻粒岩相特征; 晚期矿物仅见普通角闪石, 具绿色多色性, 常在先成的单斜辉石边缘形成反应边, 是角闪岩相退变质的产物. 这种多期退变质现

(下转 96 页)

[ 12] Wang M, Kulatilake P H S W. Discrete fracture fluid flow simulation of pumping tests in a fractured rock mass [ A] . Proceedings of the Fourth North American Mechanics Symposium [ C] . Seattle, Washington, USA: American Rock Mechanics Association, 2000. 831 —

839.

[ 13] Wang M. Discrete fracture fluid flow modeling and field applications in fractured rocks [ D] . Tucson, Arizona, USA: The University of Arizona, 2000. 303.

## Groundwater ( Fluid) Flow Modeling in Fractured Rocks via Discrete Fracture Fluid Flow Approach

Wang Mingyu<sup>1</sup>, Chen Jingsong<sup>2</sup>, Wan Li<sup>2</sup>

(1. *The University of Arizona, Tucson, Arizona 85721, USA*; 2. *Department of Water Resources and Environmental Engineering, China University of Geosciences, Beijing 100083, China*)

**Abstract:** The continuum approach in fluid flow modeling can generally be applied to porous geological media, but has limited applicability for fractured rocks. With the presence of a complex fracture network pattern and the fluid flow restricted mainly to the fractures, the porous media assumption does not adequately describe the flow behavior in the fractured rocks. A discrete fracture flow model has the capability not only in capturing inhomogeneity and anisotropy, but also in estimating representative elementary volume (REV) and determining hydraulic conductivity tensor for fractured rocks. In this paper, the following sub-topics were discussed: (a) general discrete fracture fluid flow modeling for saturated fractured geologic media; (b) determinations of REV and hydraulic conductivity tensor for fractured rocks using a discrete fracture network fluid flow model; (c) investigations of fracture orientation effect on the hydraulic conductivity and REV using a discrete fracture network fluid flow model, and (d) the ways to treat major fractures vs. minor fractures in the 2D and 3D discrete fracture fluid flow models. The results from this investigation indicate that a discrete fracture flow model could be used to evaluate the hydraulic properties at different scales. In addition, the orientation of fractures plays an important role in determining the hydraulic behaviors in fractured rocks. Furthermore, various conceptual fluid flow models are presented to reflect the different flow features of both minor and major fractures identified in fractured rock masses.

**Key words:** groundwater flow modeling; fractured rock; discrete fracture fluid flow approach; representative elementary volume; hydraulic conductivity tensor; minor fracture; major fracture.

\*\*\*\*\*

(上接 80 页)

象表明曾位于喜马拉雅造山带根部的下地壳变质杂岩经历了由高压到低压的绝热快速抬升过程,与 17 Ma 以来喜马拉雅的隆升作用密切相关。在喜马拉雅隆升、变质杂岩揭顶和基性麻粒岩剥露的过程中,麻粒岩及其相关的韧性剪切带叠加多期构造变形,不同程度地受到拆离断层和平移断层的改造。

粒岩形成于地壳深层韧性剪切带,受控于喜马拉雅造山带根部高温、高压、高应变构造环境,其成因可能与下地壳层流作用密切相关。在喜马拉雅造山带的快速隆升过程中,下地壳基性麻粒岩与角闪岩相变质岩一起剥露出地表,麻粒岩具有更快的上升速率,经历了一系列退变质降压反应,并叠加了脆-韧性和脆性构造的改造。

喜马拉雅造山带中段核部变质杂岩中的基性麻