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論 文 要 旨

Abstract

論 文 題 目

Title

FEM Simulation of the Development of Himalayan Thrust System

DETAIL ABSTRACT HAS BEEN SHOWN IN APPENDIX-1

PLEASE SEE THIS APPENDIX

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Appendix-1

Abstract

Finite element method is a general method of structural analysis in which a continuum or continuous structure is replaced by a finite number of elements interconnected at a finite number of nodal points. The method can be used to determine the displacements of the nodal points and stresses within the elements developed in two or three dimensional elastic or viscous structures of arbitrary geometrical and material properties. From this point of view, a 2D finite element method has been adopted to characterize the stress field and deformation pattern (mainly faults) in the Himalayan orogenic ranges. The Himalayas represent one of the few places on earth where continental crust is attempting to underthrust continental crust. As the Indian plate underthrusts beneath the Himalaya, it warps down in response to an advancing orogenic load and keeps the entire Himalayan mountain arc seismically active with which continuously influencing the stress field and structures in the regime. A series of elastic finite element models are presented to examine the state of stresses and faults on the models as well as within the incipient zones of major thrusts (MCT, MBT and MFT) after collision. Finally, the tectonic implementation of such simulated structures are drawn with combining the previously published geological, seismological and focal mechanism solution of faults data in the Himalayas.

The geologic profiles A, B, C and D of the central Himalaya which are used for the purpose under plane strain condition with elastic rheology. The elasticity of such model's layers considered with regards to the rock layer properties that there is a tendency, i.e. the older profiles might composed of the harder rocks and the older rock layers are the larger properties (e.g. density, Young's modulus and cohesion), whereas friction angle is lesser and Poisson's ratio is constant for all stages of models. The convergent rate of Indian plate has been considered 10 cm/a for profile A (40-20 Ma); 5 cm/a for B, C (20-10 Ma) and 2 cm/a for the present profile A (0 Ma). The results show that the compressive stress and the thrust fault dominant over the whole period after collision.

Some interesting findings of the numerical models are: (1) simulated state of

stresses is compressive in nature where σ_1 oriented horizontally, is resulting the thrust faults of the models; (2) state of stresses and intensity of failure elements (faults) are mainly controlled by the model geometry, boundary condition and layers properties; (3) displacement boundary conditions are sensitive for both of the stresses magnitude and faults whereas layer properties are mainly sensitive to the fault development; (4) thrust faults are frequently formed within the low-grade rocks layers than in the high-grade rock layers; (5) thrust faults are localized within the whole area of incipient zones of MCT (40-20 Ma), MBT (20-10 Ma) and MFT (10-0 Ma) as well as along the initial boundaries of these future thrusts; (6) faulting tendency increases in the younger rock sequences of the profiles with their propagation southward; (7) good agreement of simulated stress and thrust faults with the existed geologic records in this compressional regime; (8) numerically developed faults since 40 Ma to present are direct evidences to the transformation of active subduction of Indian continental crust from north to south; (9) localization of thrust faults along the MCT at primary stage of post collision then MBT (20-10 Ma) and finally along the MFT (10-0 Ma) suggesting that the age of initiation of these thrusts becomes from MCT to MFT, with the MCT as the oldest and MFT as the youngest; (10) intense development of fault around the major thrusts (MBT an MFT) and along the frontal part of Himalayas indicating that these areas are tectonically active which support the present neotectonics in the Himalayas.

The distribution of stress trends and faults calculated in the models are compared with the previously published geological data, earthquakes focal mechanism solutions of faults and active faults analysis data in the Himalayas. Comparison shows the close similarities between the simulated results and the aforesaid published data. Finally on the basis of the numerical modeling results and summary of former geological and geophysical researches, a preliminary hypothesis is proposed on the structural and tectonic development of the Himalayan orogeny, where especial attention has been paid for examining the earlier development stage of stress state and fault in the incipient zones of the future thrusts MCT, MBT and MFT as well as the present stage. The compressive stress and thrust faults within the incipient zones might be the responsible for the earlier development stage of MCT (40 Ma), MBT (20 Ma) and MFT (10 Ma) which may paved the way for posing that the MCT is the oldest and MFT is the youngest thrusts in the Himalayas and they are propagating southward from the initiation time. I believe that the continuous propagation of such thrusts might have greatly influenced the tectonics and structures in this compressoinal mountain belt. Presently, around the frontal part of the Himalayas might be more active which is responsible for the neotectonic activity in the regimes.

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学位（博士）論文審査及び最終試験の終了報告書

学位（博士）の申請に対し，学位論文の審査及び最終試験を終了したので，下記のとおり報告します。

記

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成績評価	学位論文 （合格） 不合格	最終試験 （合格） 不合格	
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審査要旨（2000字以内）

従来の地質学的研究から、ヒマラヤはインド大陸の南部チベットへの潜り込みに伴う滑りにより、MCT がさらに MBF が形成された。これらはいわゆる "schuppen zones" からなっている。この考えは単純化されているが、地質学のデータとは矛盾しない。また地震の断層面解の北落ちの面はこれらの断層面と考えられる。震源の深さは MBF の面と一致する。このモデルは日本や南米の沈み込み帯のものと似ているが、大陸性の地殻が潜り込む点で根本的に異なる。このような仮定の下に提案されたモデルは６つの断面図に表されている。

（次頁へ続く）

審査要旨

（1）衝突までは海洋性リソスフェアがチベットの下に潜り込んでいる。（2）衝突の時点。（3）インド地殻がチベット南部の下に潜り込む。MCT の形成開始。（4）１００km 収束し、MCT が形成された。これに伴ってできたスライスは MCT の上部にのしあがる。これはモホ面がほぼ水平であるという仮定からである。上昇部は削剥される。MBT の形成開始。（5）さらに１２５km 収束し、MBF が形成された。これに伴ってできたスライスは MCT と MBF の上部にのしあがり、ヒマラヤ中央部は大規模に上昇する。これはモホ面がほぼ水平であるという仮定からである。上昇部は削剥される。（6）その結果現在の地形と地質構造になる。

Farhad の博士論文は、このようなヒマラヤにおける thrust の定性的形成モデルを FEM を用いてより定量的に明らかにしたものである。

各層の物性定数 (density, Young's modulus, Poisson's ratio, cohesion, friction angle)のグラフを時代ごとにみると、パタンは同じになる。しかし、実際には多少の違いがある。これは MCT, MBT, MFT の発生予定域で断層の発生を多くするためにこれらの parameter をいろいろと調整したためである。

モデル断面上での応力の分布から最大圧縮応力はプレート下面に生じ、最大剪断応力はプレート表層に集中する。

これが表層に thrust が数多く発生する理由である。

重要な結論は、model A で incipient zone に MCT が発生し、model B で incipient zone に MBT が発生し、model C で incipient zone に MFT が発生した。このような thrust 形成を実現する各層の物性定数の組み合わせの一つを提示した。これはヒマラヤにおいては初の試みであり評価できる。

Muhammad Farhad Howladar による"FEM simulation of the development of Himalayan thrust system" と題された博士論文審査会は２００６年１月２５日（水）１０時から１１時までの１時間に理学部本館３２７教室で行われた。この結果から合格とする。