FOLDING OF MOHO AND GPS SURVEY IN TIBET

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Abstract: We first revealed the folding structure of the Tibetan Moho, obviously reflecting the continent-continent collision between the Indian and Eurasian plates. The structure shows excellent coincidence with modern global positioning system (GPS) observation, which indicates that the deformation of deep subsurface structure is closely connected with surface movement. We use the recent GRACE satellite-based gravity model, GGM02C as the principle gravity data. We point out some serious defects of the former method in estimating the prevailing wavelengths of the folding structure and suggest a new method and different results. Our Moho folding model is based on the gravimetric Moho undulation model and the flexural isostasy model. The low effective elastic thickness of about 35km supports the idea of Moho folding to be possible one; otherwise a strong lithosphere wouldn't be buckled. Thus our study also emphasizes that the distinctive undulation features of the Moho have been formed by buckling in compressional environment, while the greatly deep Moho is mainly due to isostatic compensation of topography. Our Moho folding model shows: (a) EW directional trend is prominent in western Tibet, while NS directional one in eastern Tibet, (b) the folding structures are not limited to the inside of the plateau but extended to the near surroundings of the plateau, (c) the amplitude of the folding is about 15km (-7.47~7.77km) inside the plateau, (d) rapid decreasing of the amplitude is observed outside the plateau, (e) the intervals between the folding troughs are observed to keep a semi-constant distance of about 330~340km, which is quite smaller than that of the previous study of about 500~700km, and (f) our results are in good agreement with the modern GPS measurements and relate with weakness and partial melting of the Tibetan lithosphere.

1. General Instructions

The Tibetan Plateau, the world's highest area is thought to be formed by collision of two continents. Due to the high topography and compression, it is also expected that Tibet should have extraordinarily thick crust and its Moho be buckled. Lots of international geophysical researches have been done to understand the structure of crust and mantle beneath the plateau and its geohistory. Though international seismic experiments have been applied in the plateau many times [1], their distributions were along only a few cross-sectional lines in central Tibet, which couldn't cover the very wide plateau. In addition, the crossing lines don't seem to be appropriate to describe the Moho folding structure in view of our results. Not many researches of gravimetric inversion [2-5] are found. Though the existence of Moho folding and its dominant wavelength are suggested before [6], the structure has not been estimated nor a method been suggested until now.

We point out some serious defects of the former method in estimating the prevailing wavelengths of the folding structure and suggest a new method and different results based on the gravity inversion model and flexural isostasy. The recovered Moho folding structure shows excellent agreement with the modern GPS measurements [7] that show surface movement of the crust. In addition, the predominant wavelength of the folding is estimated to be about 330~340km, quite different with that of the previous study of about 500~700km [6].

2. Data and Moho Model

The GGM02C (refer to http://www.csr.utexas.edu/) is the principle gravity data set. The EGM96 (higher orders than 200) and Topographic/Isostatic Gravity Model are also used to supplement the analysis. The topography data of JGP95E 5′ which was developed to support the EGM96 and sedimentary thickness model of IGG, CAS (Institute of Geodesy and Geophysics, Chinese Academy of Science) are used.

Our study starts at the Moho model by Shin *et al*. [5]. Theirs is based on the same data sets listed above and FORTRAN programs [8] based on the Parker-Oldenburg method. Overall Moho was observed to be deeper than about 47km, while the maximum depth, 79.5km is shown in west Tibet. The Moho was found to be very deep in western and middle Tibet, while a relatively shallow Moho, with values less than 65km is widely found in eastern Tibet. The three deep Moho belts (troughs) and shallow Moho belts (ridges) between them were found with a clear EW oriented trend parallel to the plateau border and tectonic lines, while a variation of the trends was observed in middle to southeast Tibet. To describe the distinctive shape of the Moho troughs beneath Tibet, they introduced the term "Moho ranges"

3. The Moho Folding Structure

We suggest that the deviations of the real Moho from the isostatic Moho can give us important clue of the Moho folding structure. The folding structure based on Airy-type isostasy, however, seems to be insufficient, because it fails to show NS directional folding troughs and ridges in eastern Tibet, where EW directional compression is observed. Thus the flexural isostatic Moho model is computed by applying the flexural rigidity filter [9] and is used instead of the local isostasy model. According to Shin *et al*. [5], the loads of waves longer than about 900km are compensated by the Airy-type isostasy. On the other hand, the loads of waves shorter than 200km are found to be fully supported by the rigidity of the lithosphere. The loads of intermediate wavelengths are observed to be supported partially by the rigidity of the lithosphere and also by vertical movement. The low effective elastic thickness of about 35km estimated by them could support the idea of Moho buckling to be possible one; otherwise a strong lithosphere wouldn't be buckled. The existence of partial melting [10-12] could be also related with the Moho folding. Our flexural rigidity filter (Fig. 2) based on the analysis above is successfully applied and give a fascinating folding structure (Fig. 1), which shows not only EW but also NS directional folding ridges and troughs.

The structure shows good agreement with Moho ranges [5] except only in a little part of eastern Tibet. It is remarkable that the dominant direction of the structure is changed from EW directional trend in western Tibet to NS directional trend in eastern Tibet, and the strongest deformation is distributed in the western Tibet and the southern border of the plateau. These could lead us to deduce the direction and size of compressional stress. These trends are also confirmed by the coincidence with the recent GPS measurements [7], which indicate the possibility of connection of surface crustal movement with the deep interior of the plateau. The amplitude of Moho folding is about 15km (-7.47~7.77km) inside the plateau and decrease rapidly outside the plateau. The prevailing wavelength of Moho folding is 330~340km from the power spectrum analysis on the Moho structure, while 375, 405 and 475km are also notable (Fig. 2). The intervals between the folding troughs are also observed to keep a semi-constant distance of about 330~340km. Though the longer waves than 340km have been also affected and deformed by the compression, our analysis indicates that they are mainly originated from the isostatic compensation. Jin *et al*. [6] suggested that the prevailing folding occurred at two wave bands centered around 150~200km (upper crust) and 500~700km (upper mantle) in Tibet. Our estimation based on the gravimetric Moho model and the flexural rigidity filter is different from them in methodology that is based on the spectral analyses of topography and gravity. The latter has to overcome two defects: (a) the intrinsic risk of Gibbs phenomenon in Fourier analysis and

(b) the rate of erosion against the topography. However, the former study used the sensitive method without mentioning how the problems were treated.

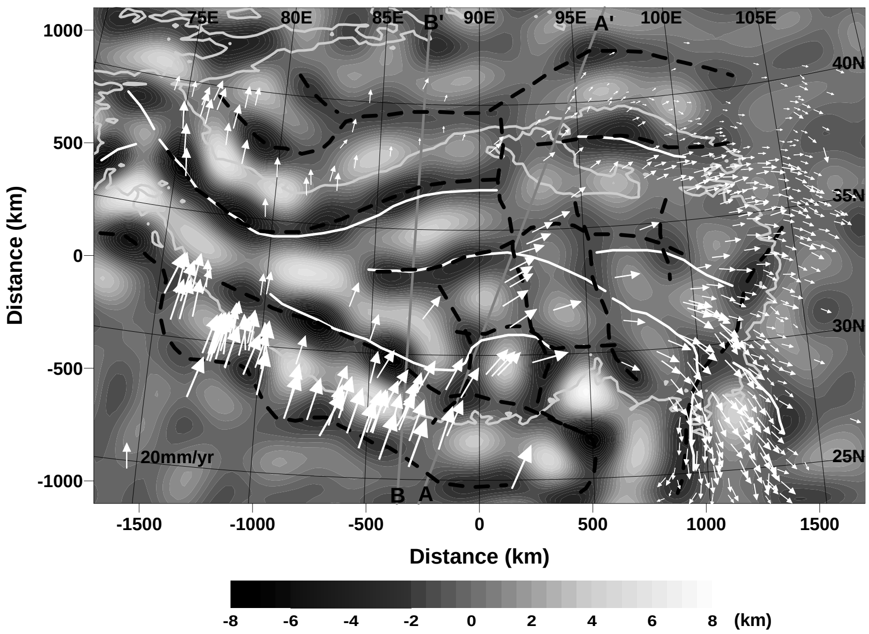

Fig. 1. Moho folding structures and surface movement from GPS: The dashed lines denote EW and NS directional folding troughs. The Moho ranges [5] (white lines) are shown for comparison. The white arrows represent the surface movement measured by GPS [7]. The grey line enclose the plateau is 3km-height contour. Cross-sections along AA' and BB' are presented in Fig. 3.

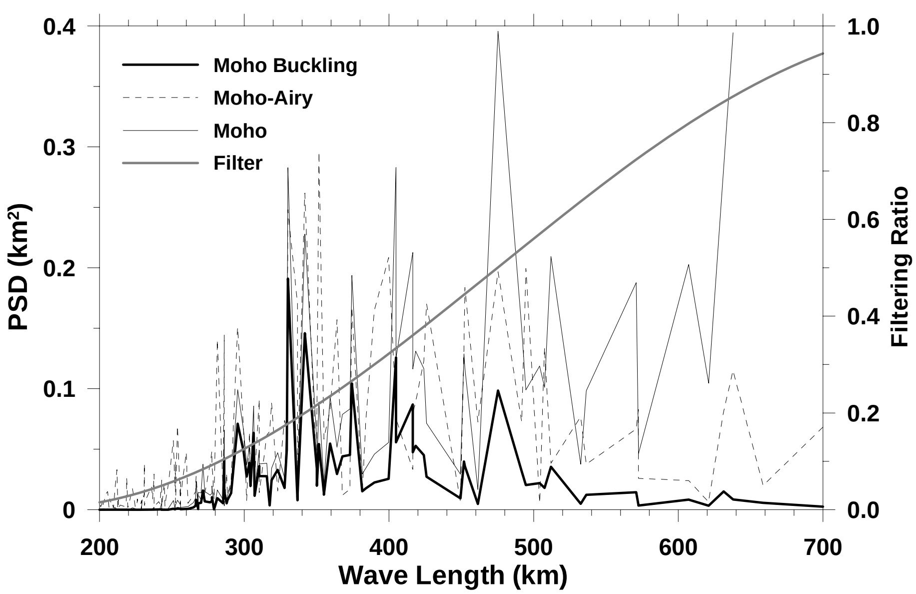

Fig. 2. Power spectral density of the Moho folding and the flexural rigidity filter: The dominant wavelengths of Moho folding are 330~340km, while 375, 405 and 475km are also notable. The filter is designed to fit well with the observed coherence between gravity and topography [5].

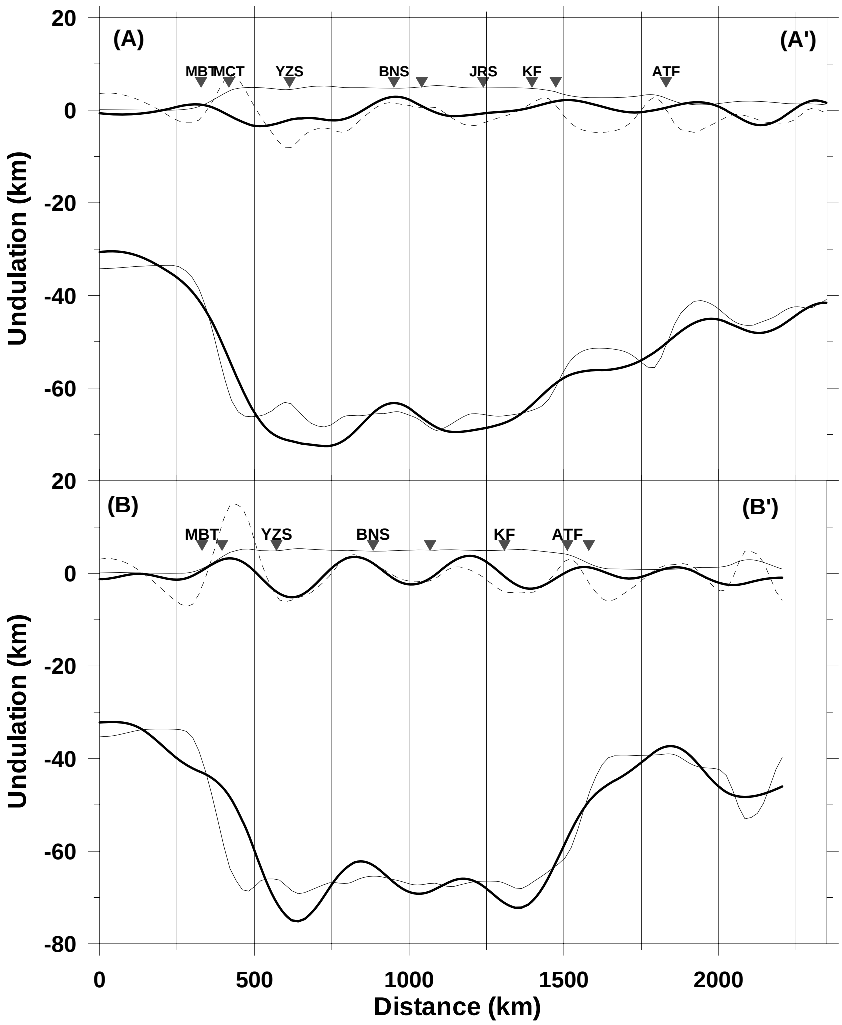

Fig. 3. Cross-sectional view along AA' and BB': The thin lines denote topography (up) and Airy-type isostatic Moho (down). The thick lines represent the Moho folding (up) and gravimetric Moho (down), and the dashed line the difference of the two Mohos. The inverse triangles represent cross-over points with tectonic lines shown with acronyms like MBT (Main Himalaya Thrust), MCT (Main Central Thrust), YZS (Yarlung-Zangbo Suture), BNS (Bangong-Nujiang Suture), JRS (Jinsha River Suture), KF (Kunlun Fault), and ATF (Altyn Tagh Fault). Ratio of y-axis/x-axis is 15.

The folding structure in the cross-section along the line BB' (Fig. 3) shows the wave has an even amplitude and wavelength of about 330~340km, while the amplitude outside the plateau reduces rapidly. In contrast to the topography and the isostatic Moho inside the plateau, the gravimetric Moho shows wavy variation apparently, which can be an evidence of buckling. When the cross-sectional line is not perpendicular to the folding structure like AA', the regularity is hardly observable. That explains the reason why the major seismic profile [1] didn't show the wavy pattern of Moho folding. Thus our study suggests that the distinctive Moho ranges [5] and the well known shallow Moho along BNS [1-5] were formed by the compressional environment, while the huge and deep Moho was originated mainly from vertical movements by the isostatic compensation and partly from buckling. The Moho ranges and its Moho folding structure of Tibet and its vicinity, a fossil for the compressional stress and its variation due to the India-Eurasia collision, can be a key in understanding the geohistory of Tibet. Thus our study would be useful for further geophysical interpretation and exploration.

4. References

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