Green's function elements obtained from Fireballs-96 (*20*). This is a pseudopotential density functional technique, implemented here with a minimal numerical basis for H, C, and S, and an sp^3d^5 basis for Au. The molecular structure was first optimized with Hellmann-Feynman forces, with the molecule embedded in an infinite octanedithiol matrix between two gold slabs. The two-dimensional unit cell consisted of an octanedithiol molecule connected at each end to a 2 × 2 Au surface. The terminal H was removed from each thiol group, and the sulfur atoms were found to bind to the gold about 0.194 nm above the surface and equidistant from three Au surface atoms. The current was calculated for this geometric structure by contacting a single molecule between a pair of Au(111) clusters four by four by five atoms deep (avoiding technical problems for current calculations in an infinite system). A similar process was used for the nonbonded structure.

19. V. Mujica, M. Kemp, M. A. Ratner, *J. Chem. Phys.* **101**, 6849 (1994).
20. A. A. Demkov, J. Ortega, O. F. Sankey, M. P. Grumbach, *Phys. Rev.* **B52**, 1618 (1995).
21. J. I. Siepmann, I. R. McDonald, *Phys. Rev. Lett.* **70**, 453 (1993).
22. J. B. Schlenhoff, M. Li, H. Ly, *J. Am. Chem. Soc.* **117**, 12528 (1995).

23. We thank L. Nagahara (Motorola Labs) and G. Ramachandran (Arizona State University) for useful discussions. Supported by NSF.

12 July 2001; accepted 27 August 2001

Present-Day Crustal Deformation in China Constrained by Global Positioning System Measurements

Qi Wang,[1] Pei-Zhen Zhang,[2]* Jeffrey T. Freymueller,[3]
Roger Bilham,[4] Kristine M. Larson,[5] Xi'an Lai,[1] Xinzhao You,[1]
Zhijun Niu,[2] Jianchun Wu,[2] Yanxin Li,[6] Jingnan Liu,[7]
Zhiqiang Yang,[8] Qizhi Chen[3]

Global Positioning System (GPS) measurements in China indicate that crustal shortening accommodates most of India's penetration into Eurasia. Deformation within the Tibetan Plateau and its margins, the Himalaya, the Altyn Tagh, and the Qilian Shan, absorbs more than 90% of the relative motion between the Indian and Eurasian plates. Internal shortening of the Tibetan plateau itself accounts for more than one-third of the total convergence. However, the Tibetan plateau south of the Kunlun and Ganzi-Mani faults is moving eastward relative to both India and Eurasia. This movement is accommodated through rotation of material around the eastern Syntaxis. The North China and South China blocks, east of the Tibetan Plateau, move coherently east-southeastward at rates of 2 to 8 millimeters per year and 6 to 11 millimeters per year, respectively, with respect to the stable Eurasia.

Asia is a modern example of large-scale continental deformation (Fig. 1) and an ideal natural laboratory for its studies. Unfortunately, much of the region is remote, and thus the kinematics of Asia has been, until recently, poorly understood. Although much of its late Cenozoic deformation is explained by the collision and subsequent penetration of India into Eurasia (*1*), how Eurasia deforms in response to the collision is still subject to debate (*2, 3*), and a complete kinematic description of deformation over the entire region has not been available. Existing kinematic models (*4, 5*) rely on sparse data sets that can only describe the complex deformation of Eurasia on length scales of 200 km or larger, and lack data from critical regions. We present a synthesis of GPS velocities in China and its vicinity that provides new insights into the kinematics of Eurasia.

Much of the actively deforming part of Eurasia lies within China, including the Tibetan plateau, and parts of the Himalaya, Tian Shan, and Pamir mountain ranges (Fig. 1). Since the early 1990s, several regional GPS networks for active tectonic studies were established in China and neighboring regions (*6–15*). These networks were surveyed in campaign mode, usually at 1- to 2-year intervals. Each individual network was originally designed to address local problems, and it has been difficult to merge the data together, due to different data analysis strategies. We obtain a self-consistent velocity field by analyzing the original raw data from several different regional networks and merging them into a self-consistent solution.

We combined original data from GPS campaigns carried out between 1991 and 2001 by 10 Chinese and U.S. agencies or universities (*16*). The regional GPS data were combined with continuous tracking data from a well-distributed set of global International GPS Service (IGS) stations using the GIPSY software (*17*). For data observed between 1991 and 1995, we used a global solution strategy in which parameters associated with GPS satellite orbits were estimated together with all station coordinates (*18*). A projection operator was applied to the covariance matrix to remove the components of the covariance matrix that are purely due to reference frame uncertainty (*19*). For data observed after 1995, a regional solution strategy was adopted, using fixed orbits and satellite clocks provided by NASA's Jet Propulsion Laboratory (*20*). A subset of IGS stations was used in the regional solutions (*21*). Next, the daily free network solutions were each transformed into the ITRF97 (International Terrestrial Reference Frame, epoch 1997.0) by estimating a seven-parameter similarity transformation for each (*22*). We estimated the transformation for each day, on the basis of the common stations that are present both in ITRF97 and in the daily solution, and weighted each station by their respective uncertainties. The 1250 daily solutions were used as data to determine the station velocities and station coordinates at epoch 1995.0 by a standard weighted least-squares adjustment (*23*). The velocities in ITRF97 were then transformed into velocities in a Eurasia-fixed reference frame (*24*). The aggregate velocity solution of 354 stations (*25*) provides an image, to date, of present-day crustal deformation in Asia (Fig. 2). The velocity solutions in both ITRF97 and Eurasia-fixed frames are available at *Science*'s Web site (*26*). Most velocity uncertainties, propagated by the errors of Eurasia rotation parameters, are in the range of 1 to 4 mm/year, except some stations with an observation interval shorter than 1.5 years. The mean uncertainties in northward velocities relative to Eurasia are 2.2 mm/year and 2.4 mm/year for eastward components.

Stations located on the northern Ganges plains, south of the Himalaya, show northward movement (N19°-22°E) at a rate of 36 to 38 mm/year with respect to stable Eurasia (*27*), consistent with some previous studies (*5, 13, 28*). Bangalore (station IISC) in southern India has a velocity of 35.9 ± 1.0 mm/year in the direction of N26.9° ± 1.7°E. The

---

[1]Institute of Seismology, China Seismological Bureau, Wuhan 430071, China. [2]Center for Crustal Movement Studies and Institute of Geology, China Seismological Bureau, Beijing 100029, China. [3]Geophysical Institute, University of Alaska, Fairbanks, AK 99775, USA. [4]Department of Geological Sciences and CIRES, University of Colorado, Boulder, CO 80309, USA. [5]Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO 80309, USA. [6]First Crustal Deformation Monitoring Center, China Seismological Bureau, Tianjin 300180, China. [7]School of Geodesy and Geomatics, Wuhan University, Wuhan, 430071, China. [8]Department of Surveying Engineering, Chang'an University, Xi'an 710064, China.

*To whom correspondence should be addressed. E-mail: peizhen@public3.bta.net.cn.