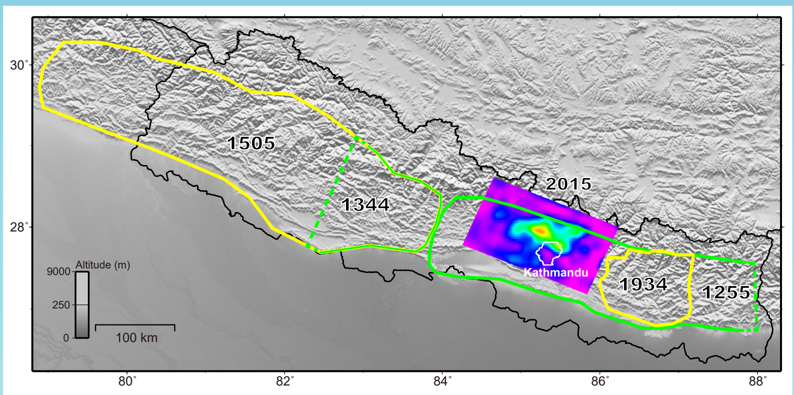
Earth, Planets and Space

Active Tectonics and Seismic Hazards in the Himalayan Region



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Earth, Planets and Space

Koketsu *et al. Earth, Planets and Space (2025) 77:55*
https://doi.org/10.1186/s40623-025-02181-1

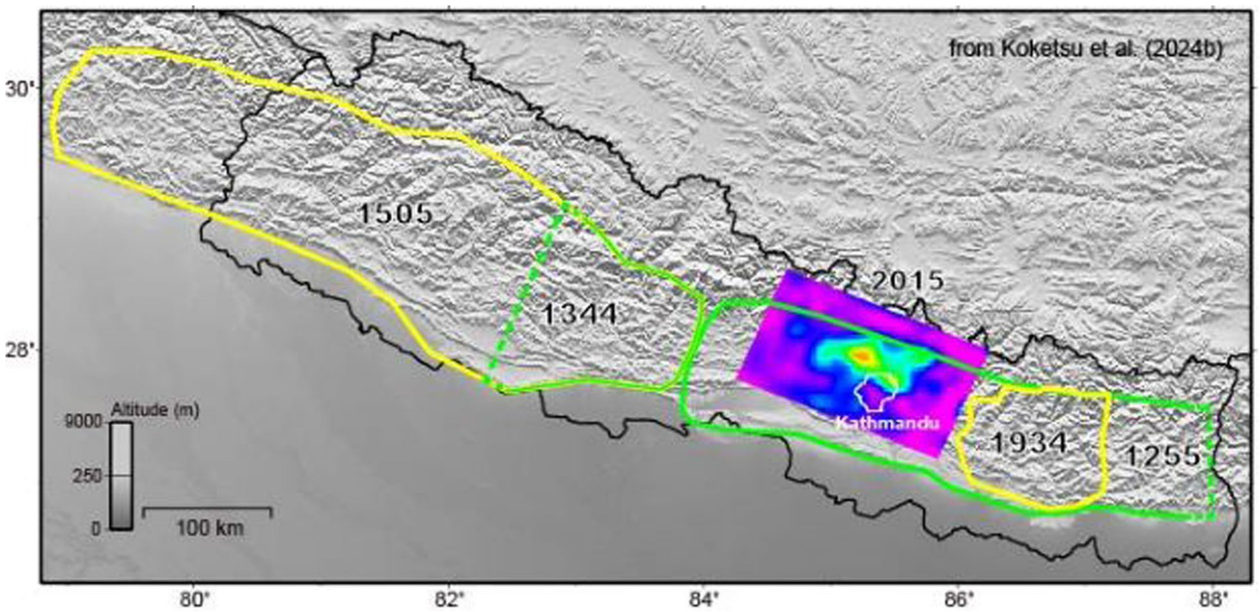
PREFACE

Open Access

Special issue "active tectonics and seismic hazards in the Himalayan region"

Kazuki Koketsu[1*], Srinagesh Davuluri[2], Laurent Bollinger[3] and Phil Cummins[4]

Graphical Abstract



In the Himalayan region, the Indian plate is colliding with the Eurasian plate, and the Indian lithosphere is being underthrust along the Main Himalayan Thrust (MHT). This active tectonics has generated large earthquakes as depicted in the graphical abstract, and is driving future seismic hazards in the region. In light of this situation, we proposed a special issue titled "Active Tectonics and Seismic Hazards in the Himalayan Region" and have accepted a frontier letter and five full papers.

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Koirala et al. (2023) studied seismic clusters on the MHT. Koketsu et al. (2024a) constructed a velocity structure model in the region. Tabei et al. (2024) modeled interseismic plate coupling distribution on the MHT. Shigefuji et al. (2024) and Prajapati et al. (2024) investigated the structures of sediments in the basin of Kathmandu and in the Bhaktapur district. Koketsu et al. (2024b) constructed a future scenario earthquake and assessed ground motion hazards for Kathmandu. Koirala et al. (2023) also includes a review of the aforementioned situation and research on it.

Author contributions

All authors served as guest editors for this special issue. KK drafted the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare that they have no competing interests.

Published online: 24 April 2025

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Koirala BP, Laporte M, Bollinger L, Batteux D, Letort J, Trilla AG, Nicolas Wendling-Vazquez N, Bhattarai M, Subedi S, Adhikari LB (2023) Tectonic significance of the 2021 Lamjung, Nepal, mid-crustal seismic cluster. Earth Planets Space 75:165. https://doi.org/10.1186/s40623-023-01888-3

Koketsu K, Suzuki H, Guo Y (2024a) Three-dimensional velocity structure models in and around the Kathmandu Valley. Central Nepal Earth Planets Space 76:6. https://doi.org/10.1186/s40623-023-01954-w

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Prajapati R, Dhonju S, Bijukchhen SM, Shigefuji M, Takai N (2024) Estimation of Vs30 and site classification of Bhaktapur district, Nepal using microtremor array measurement. Earth Planets Space 76:135. https://doi.org/10.1186/s40623-024-02077-6

Shigefuji M, Takai N, Bijukchhen SM, Timsina C, Bhattarai M (2024) Examination of shallow and deep S-wave velocity structures from microtremor array measurements and receiver function analysis at strong-motion stations in Kathmandu basin. Nepal Earth Planets Space 76:72. https://doi.org/10.1186/s40623-024-02020-9

Tabei T, Ohzono M, Silwal BR, Bhandari RP, Adhikari LB, Chand JB, Kandel TP (2024) Geodetic plate coupling and seismic potential on the main Himalayan thrust in Nepal. Earth Planets Space 76:68. https://doi.org/10.1186/s40623-024-02016-5

Publisher's Note

FRONTIER LETTER Open Access

Tectonic significance of the 2021 Lamjung, Nepal, mid-crustal seismic cluster

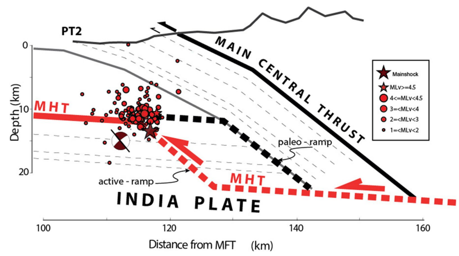
Bharat Prasad Koirala*, Marine Laporte, Laurent Bollinger*, Daria Batteux, Jean Letort, Aurélie Guilhem Trilla, Nicolas Wendling-Vazquez, Mukunda Bhattarai, Shiba Subedi and Lok Bijaya Adhikari

Earth, Planets and Space 2023, **75**:165 DOI: 10.1186/s40623-023-01888-3
Received: 23 March 2023, Accepted: 24 August 2023, Published: 18 October 2023

Abstract

Since the M_w 7.9 Gorkha earthquake of April 25, 2015, the seismicity of central and western Nepalese Himalaya has been monitored by an increasing number of permanent seismic stations. These instruments contribute to the location of thousands of aftershocks that occur at the western margin of the segment of the Main Himalayan Thrust (MHT) that ruptured in 2015. They also help to constrain the location of seismic clusters that originated at the periphery of the fault ruptured by the Gorkha earthquake, which may indicate a migration of seismicity along the fault system. We report here a seismic crisis that followed the Lamjung earthquake, a moderate M_w 4.7 event (M_L 5.8, M_{Lv} 5.3) that occurred on May 18, 2021, about 30 km west of the Gorkha earthquake epicenter at the down-dip end of the locked fault zone. The study of the hypocentral location of the mainshock and its first 117 aftershocks confirms mid-crustal depths and supports the activation of a 30–40° dipping fault plane, possibly associated with the rupture of the updip end of the MHT mid-crustal ramp. The cluster of aftershocks occurs near the upper decollement of the thrust system, probably in its hanging wall, and falls on the immediate northern margin of a region of the fault that has not been ruptured since the 1344 or 1505 CE earthquake. The spatio-temporal distribution of the first 117 aftershocks shows a typical decrease in the associated seismicity rate and possible migration of seismic activity. Since then, the local seismicity has returned to the pre-earthquake rate and careful monitoring has not revealed any large-scale migration of seismicity towards the locked fault segments.

Keywords: Earthquake, Clustered seismicity, Main Himalayan Thrust, Himalaya, Nepal



Graphical abstract

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FULL PAPER Open Access

Geodetic plate coupling and seismic potential on the main Himalayan thrust in Nepal

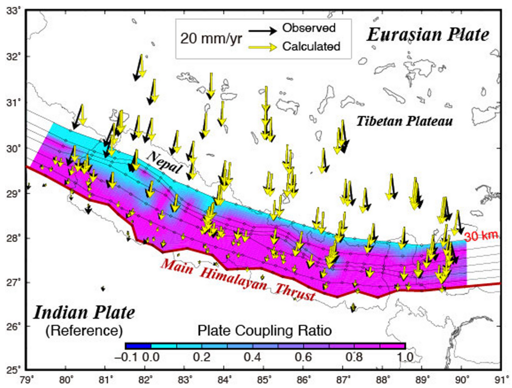
Takao Tabei*, Mako Ohzono, Bishow R. Silwal, Rajendra P. Bhandari, Lok B. Adhikari, Janak B. Chand and Thakur P. Kandel

Earth, Planets and Space 2024, **76**:68 DOI: 10.1186/s40623-024-02016-5
Received: 18 December 2023, Accepted: 23 April 2024, Published: 8 May 2024

Abstract

We model interseismic plate coupling distribution on the Main Himalayan Thrust (MHT) in Nepal through the inversion of secular GNSS velocity data. To complement previously published data, we compile velocity data from ten additional continuous stations to improve spatial resolution in central and mid-western Nepal. A regional non-planar structural model is adopted to reproduce the MHT fault plane. In general, the coupling pattern seems nearly binary, indicating that transition from full coupling to decoupling is occurring sharply in very narrow zones. In eastern Nepal (> 84.5ºE), plate coupling is very strong from the surface to intermediate depths, including the source region of the 2015 Mw 7.8 Gorkha earthquake. Geodetically estimated slip deficit rates are consistent with the rupture history of great earthquakes in the east revealed by geomorphological observations. In the west (< 83.0ºE), a weakly coupled zone extends laterally at intermediate depths, whereas the coupling in the shallower part remains very strong. Although the slip deficit rate in the west is significantly smaller than that in the east, seismic moment accumulated, since the last complete rupture in 1505 may be capable of generating a future great event. In central Nepal, estimated slip deficit rates are comparable with those in the east, and no great event has been documented over the past several centuries. Thus, the seismic risk may be most urgent in central Nepal. The development of local seismicity and crustal deformation should be carefully monitored.

Keywords: Plate coupling, Main Himalayan Thrust, GNSS, Crustal deformation, Seismic potential



Graphical abstract

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FULL PAPER **Open Access**

Examination of shallow and deep S-wave velocity structures from microtremor array measurements and receiver function analysis at strong-motion stations in Kathmandu basin, Nepal

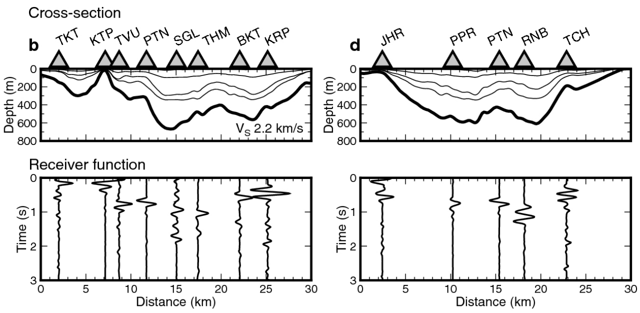
Michiko Shigefuji*, Nobuo Takai, Subeg Man Bijukchhen, Chintan Timsina and Mukunda Bhattarai

Earth, Planets and Space 2024, **76**:72 DOI: 10.1186/s40623-024-02020-9
Received: 27 December 2023, Accepted: 29 April 2024, Published: 13 May 2024

Abstract

The Himalayan collision zone, where the Indian Plate subducts beneath the Eurasian Plate at a low angle, has caused many devastating earthquakes. The Kathmandu basin, situated in this region, is surrounded by mountains on all sides and is filled with distinct soft lake sediments with a highly undulating bedrock topography. The basin has been experiencing rapid urbanization, and the growing population in its major cities has increased the vulnerability to seismic risk during future earthquakes. Several strong-motion stations have recently been deployed in the Kathmandu basin. It is expected that the data captured by this strong-motion station array will further enhance our understanding of site amplification in sedimentary basins. Clear P-to-S converted waves have been observed in the strong-motion records. In this study, we investigate the medium boundary that generated these converted waves. First, we estimate the shallow velocity structures, which correspond to the topographic slopes or surface geology, beneath the strong-motion stations. We then apply a receiver function analysis to the strong-motion records. The receiver function indicates that the interface between the soft sediment and seismic bedrock serves as a boundary that generates converted waves. The obtained results can be used for tuning three-dimensional velocity structures.

Keywords: Kathmandu basin, Strong-motion record, Receiver function analysis, Microtremor array measurements, V_{S30}



Graphical abstract

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FULL PAPER **Open Access**

A future scenario earthquake and ground motion hazards for Kathmandu, Nepal

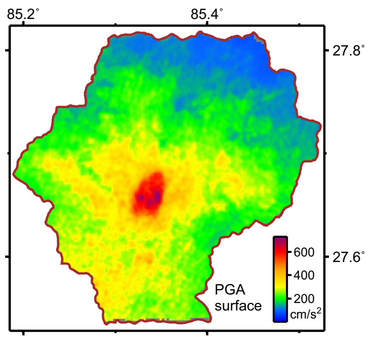
Kazuki Koketsu*, Hiroe Miyake, Koji Okumura and Haruhiko Suzuki

Earth, Planets and Space 2024, **76**:75 DOI: 10.1186/s40623-024-02018-3
Received: 29 December 2023, Accepted: 29 April 2024, Published: 20 May 2024

Abstract

Since Nepal is an earthquake-prone country due to the collision of the Indian and Eurasian plates, it is crucial for its capital of Kathmandu to evaluate ground motion hazards from a future large earthquake. For this purpose, we constructed a realistic scenario earthquake with realistic rupture parameters in a likely location. To obtain the location, a new distribution of the rupture zones of large historical earthquakes along the Main Himalayan Thrust (MHT) was obtained by integrating the distribution from a previous study and the results of trench surveys. Global Navigation Satellite System observations indicated that the plate boundary is strongly coupled from the southern boundary of the MHT to a depth of approximately 10 km and there is almost no lateral change in the coupling. This implies that all regions along the MHT have similar rates of strain increase. Therefore, it is most probable that the rupture zone of the oldest previous event will rupture as a scenario earthquake. In the new distribution, the 1255 earthquake is the oldest. However, large earthquakes occurred in 1934 and 2015 within its rupture zone. Thus, we adopted the area obtained by removing the 1934 and 2015 rupture zones from the western part of the 1255 rupture zone. The relationship between the rupture area size and seismic moment of the 2015 earthquake lies between the scaling formulas for crustal earthquakes and plate-boundary earthquakes, but is closer to the former. Therefore, using this and the scheme for characterized source models, we determined realistic rupture parameters. We then simulated broadband ground motions in Kathmandu using these rupture parameters, our 3-D velocity structure models, and a hybrid method combining the finite-difference method and the stochastic Green's function method. We obtained the peak ground accelerations (PGAs) of simulated ground motions, and calculated the seismic intensities in the Modified Mercalli intensity scale from the PGAs as indexes of hazards for Kathmandu. Intensities IX coincide with the center of the Kathmandu Valley, and intensities VIII and VII are found in the area surrounded by the sedimentary boundary and the southernmost part of the valley.

Keywords: Broadband ground motions, Characterized source model, Kathmandu Valley, Main Frontal Thrust, Main Himalayan Thrust, Scenario earthquake



Graphical abstract

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FULL PAPER Open Access

Estimation of Vs30 and site classification of Bhaktapur district, Nepal using microtremor array measurement

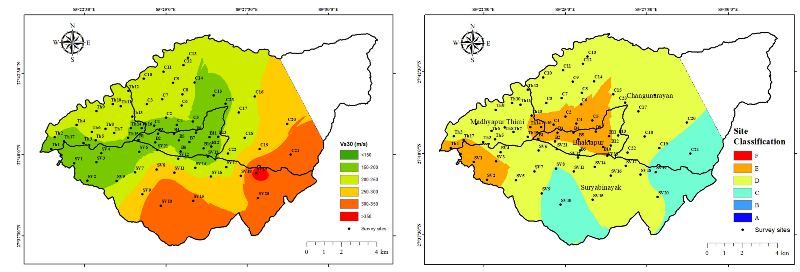
Roshan Prajapati*, Salim Dhonju, Subeg Man Bijukchhen, Michiko Shigefuji and Nobuo Takai

Earth, Planets and Space 2024, **76**:135 DOI: 10.1186/s40623-024-02077-6
Received: 30 December 2023, Accepted: 4 October 2024, Published: 25 October 2024

Abstract

The severe damage observed in the Kathmandu Basin, Nepal, during past earthquakes necessitates a thorough study of the seismic behavior of the basin sediments. As the shear-wave velocity is directly related to the elastic shear modulus of the material, it is essential to determine it to incorporate the behavior of the soil in the design of the structure. Hence, we determined average shear-wave velocity in upper 30 m (Vs30) of soil in Bhaktapur district in the eastern part of the Kathmandu Basin at 73 observation points, employing two methods involving the use of non-invasive microtremor array measurements (MAMs). These MAMs are widely used for determining subsurface soil characteristics by analyzing the ambient vibrations of the ground. The first method involves inversion using a genetic algorithm, and the second is a method for obtaining Vs30 directly from the dispersion curve. We found that Vs30 in the southeastern part of the study area was higher than that in other parts. Conversely, Vs30 in the western region was lower. The calculated Vs30 values were used to classify the sites. The elevated eastern and southeastern areas with high Vs30 were categorized as dense soil or soft rock, whereas the areas with low Vs30 that had suffered significant damage during the 2015 Gorkha earthquake were classified as soft soil sites.

Keywords: Microtremor array measurement, Vs30, Spatial autocorrelation method, Phase velocity dispersion curve, Site classification



Graphical abstract

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TECHNICAL REPORT Open Access

Three-dimensional velocity structure models in and around the Kathmandu Valley, Central Nepal

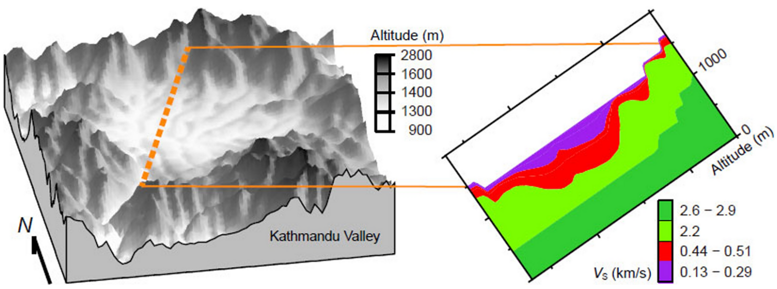
Kazuki Koketsu*, Haruhiko Suzuki and Yujia Guo

Earth, Planets and Space 2024, **76**:6 DOI: 10.1186/s40623-023-01954-w
Received: 17 July 2023, Accepted: 19 December 2023, Published: 8 January 2024

Abstract

We analyzed observations of microtremors and seismic ground motion to determine the depths of sedimentary interfaces and basement surface in the Kathmandu Valley. The results of these analyses and a reflection survey were combined to produce a data set of seismic depths for sedimentary interfaces and basement surface in the valley. Moreover, we introduced a data set of gravimetric depths, which had been produced for the basement surface from gravity observations. Because both sets of data differ in accuracy and number, we adopt the Sequential Gaussian Co-Simulation to generate the depth distributions of the sedimentary interfaces and basement surface. This method includes the cokriging approach, wherein the seismic and gravimetric depths are used as primary and secondary data, respectively. A three-dimensional velocity structure model of the Kathmandu Valley was constructed from the obtained depth distributions, which showed that the sedimentation in the valley is mainly related to the Paleo-Kathmandu Lake. Subsequently, we incorporated this model into a previous regional-scale model, and revised the latter to solve the issues of the extension of the underthrusting lithosphere and the S-wave velocity in its adjacent area.

Keywords: Kathmandu Valley, Central Nepal, Velocity structure, Seismic survey, Gravity survey



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A Grant-in-Aid for Publication of Scientific Research Results (24HP2006) from Japan Society for the Promotion of Science is used for printing.

Contents

Cover image: Koketsu, K. *et al.*, *Earth, Planets and Space* 2025, **77**:55 DOI: 10.1186/s40623-025-02181-1