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Crustal structure of central Myanmar (Burma) by surface wave dispersion

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सार–भूकम्पीय शोध वेधशाला, चेंग माय, थाइलैंड में अभिलेखित, पश्चिमी नेपाल में आए दो भूकम्पों के सतहीय तरंगों के आंकिक अभिलेखों का विश्लेषण किया गया है। शोर मुक्त सतहीय तरंगें प्राप्त करने के लिये, आंकिक आंकड़ों को, निस्यंदक फिल्टर और प्रावस्था साम्य विधियों से संसाधित किया गया है। इन शोर मुक्त सतहीय तरंगों के आवृत्ति-समय विश्लेषण से लव और रेलेह तरंगों की समूह-गतियां ज्ञात की गई हैं। मूल विधा की रेलेह तरंगों और लव तरंगों के लिये समूह गतियों के आवर्तमान क्रमशः 17 से 62 सेकेंड तथा 17 से 66 सेकेंड पाए गए। सतहीय तरंगों के पथ केन्द्रीय म्यांमार (बर्मा) और हिन्द-गंगेय मैदानों से गुजरते हैं। अतः सतहीय तरंगों के समूह गति के आंकड़े, हिन्द-गंगेय मैदानों पर सतहीय तरंगों के पथ के लिये संशुद्ध कर लिये गये हैं। आंकड़ों के अतिलोमन से केन्द्रीय म्यांमार (बर्मा) की औसत भूपर्पटी और उप भूपर्पटी संरचना का पता चलता है। मॉडल संरचना से 8 किमी० मोटाई की दो भिन्न-भिन्न अवसादी सतहों का पता चलता है। निचली अवसादी सतह भूपर्पटी का न्यूनगति वाला क्षेत्र है। केन्द्रीय म्यांमार (बर्मा) की भूपर्पटी की कुल मोटाई 55 किमी० पाई गई।

ABSTRACT. Digital records of seismic waves observed at Seismic Research Observatory, Cheng Mai, Thailand have been analysed for two earthquakes in western Nepal. Digital data are processed by the floating filter and phase equalization methods to obtain surface waves free from noise. Group velocities of Love and Rayleigh waves are obtained by frequency time analysis of these noise free surface waves. The period of group velocities ranges from 17 to 62 sec for fundamental mode Rayleigh waves and from 17 to 66 sec for fundamental mode Love waves. The wave paths cross both central Myanmar (Burma) and the Indo-Gangetic plain. The group velocity data of surface waves across central Myanmar (Burma) have been obtained after correction of the data for the path across the Indo-Gangetic plain. Inversion of data gives the average crustal and subcrustal structure of central Myanmar (Burma). The modelled structure shows two separate sedimentary layers each of 8 km thick. The lower sedimentary layer forms the low velocity zone of the crust. The total thickness of central Myanmar (Burma) crust is found to be 55 km.

Key words — Surface wave dispession. Rayleigh wave. Love wave. Epicentre. Frequency-time analysis (FTAN).

1. Introduction

The dispersion of seismic surface waves is widely used to obtain the average crustal and upper mantle structure in a region. The availability of digital data and improved data processing technique allow us to obtain dispersion data over a wide range of period and with further precision. Here we have used the long period digital records of the Seismic Reseach Observatory, Cheng Mai (CHTO), Thailand for two earthquakes in western Nepal (Fig. 3). The parameters of the two earthquakes are obtained from the Bulletin of the International Seismological Centre and are given in Table 1. The vertical, radial and transverse components of seismograms at CHTO from earthquake 1 (Table 1) are shown in Fig. 1. The first two components are used to obtain Rayleigh wave group velocity and transverse component is used to obtain Love wave group velocity.

The wave paths (Fig. 3) cross the Indo-Gengetic plain and then central Myanmar (Burma). The group velocity across the Indo-Gangetic plains was obtained earlier by Chaudhury (1966). We obtain the group velocity of surface waves across central Myanmar (Burma) after correcting the data for the path across the Indo-Gangetic plain. These group velocity data are used here to obtain the crustal and subcrustal structure of central Myanmar (Burma).

Central Myanmar (Burma) is bordered by the Indo-Burman ranges in the west and the eastern highlands in the east. It is generally believed that the Indo-Burman ranges were formed in cenozoic period as a result of subduction of the Indian plate under the Asian plate. The boundary of Indian plate is shown in Fig. 3. Shortening has apparently taken place more or less continuously from late Cretaceous to the present. On the other hand the eastern highlands belong to the Indo-China block which probably collided with the south China plate in upper Triassic (Mitchell 1981). The main part of central Myanmar (Burma) consists of the central lowlands that extend north-south as a broad fluvial plain, approximately 200 km wide and only a few tens of metres above sea level. The crustal structure of such an area is complex and since detailed structure is not available,

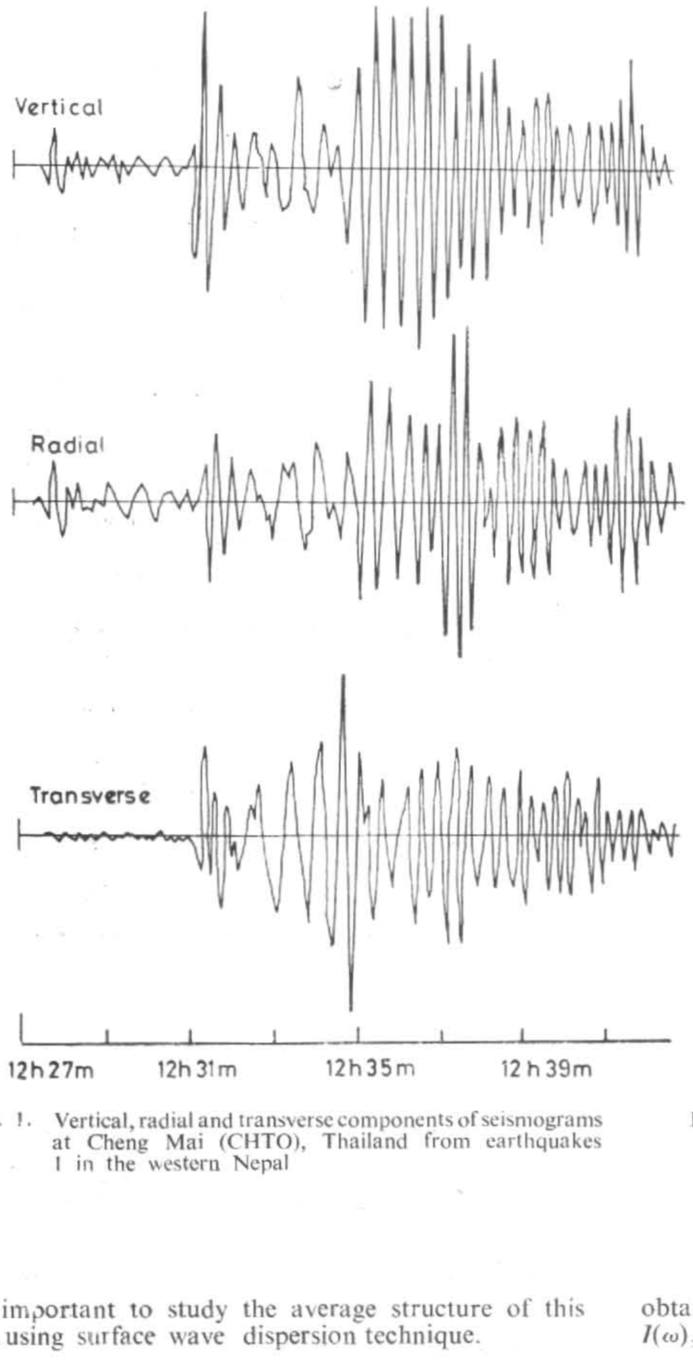


Fig. 1. Vertical, radial and transverse components of seismograms at Cheng Mai (CHTO), Thailand from earthquakes I in the western Nepal

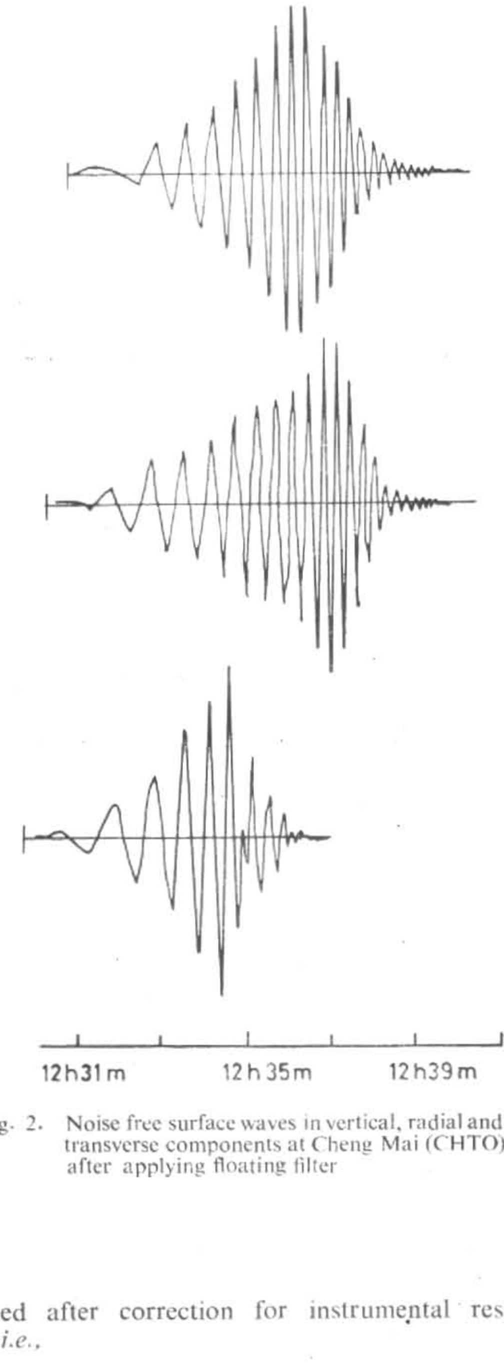


Fig. 2. Noise free surface waves in vertical, radial and transverse components at Cheng Mai (CHTO) after applying floating filter

it is important to study the average structure of this area using surface wave dispersion technique.

2. Analysis technique

Frequency-time analysis (FTAN) is performed by multiple narrow band Gaussian filtering (Dziewonski *et al.* 1969, Levshin and Berteussen 1979, Bhattacharya 1983).

$$S(\omega, t) = \frac{1}{\sqrt{2\pi}} \int_0^{\infty} K(\omega) \exp(-i\omega t) \exp\left[-\alpha_j \left(\frac{\omega-\omega_j}{\omega_j}\right)^2\right] d\omega$$

where, j is the number of the filter, α_j is a suitable constant and $K(\omega)$ is the Fourier transform of the signal $f(t)$ obtained after correction for instrumental response $I(\omega)$, *i.e.*,

$$K(\omega) = K_0(\omega)/I(\omega)$$

$$K_0(\omega) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t) \exp(i\omega t)\, dt$$

The real and imaginary parts of $S(\omega_j, t)$ give the amplitude $a_j(t)$ and phase $\psi_j(t)$ at equal time intervals. FTAN displays two dimensional plot of amplitude a_{ij} for frequency ω_j and time t_i. For $\omega = \omega_j$ the time of maximum amplitude gives the group time. However, for each ω_j, the accurate group time $t_m(\omega_j)$ is estimated by parabolic interpolation. Lander (1989) has shown that when one measure at the edge of the signal frequency band, the group time, $t_m(\omega_j)$, does not exactly

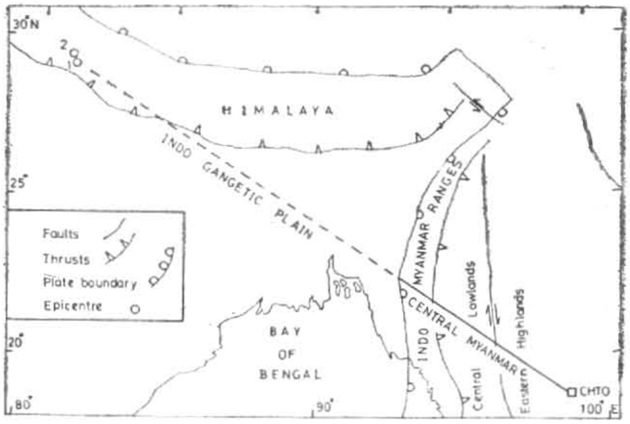


Fig. 3. The surface wave path from earthquakes to CHTO. The path across central Myanmar (Burma) is shown by continuous line and that across Indo-Gangetic basin by broken line

correspond to group time at frequency ω_j and the error is reduced by estimating the frequency of group time $t_m(\omega_j)$ as

$$\hat{\omega}_j = \left.\frac{\partial \Psi}{\partial t}\right|_{\omega=\omega_j}$$

Further, FTAN generally contains non-stationary noise which are present in a seismogram. We use floating filter and phase equalization method (Lander 1989) and obtain noise free surface waves such as shown Fig. 2. FTAN is again applied on these noise free surface waves to obtain group velocity.

3. Data and inversion

The group velocity U for the fundamental mode Rayleigh and Love waves for the entire path (Fig. 3) are shown in Figs. 4 (a & b). The wave paths cross central Myanmar (Burma) as well as the Indo-Gangetic plain. The group velocity across the Indo-Gangetic plain was obtained by Chaudhury (1966) and are shown in Figs. 4 (a & b) by continuous lines. The group velocity across the Indo-Gangetic plain remains higher than that across the present path. The difference is obviously due to a lower group velocity across central Myanmar (Burma) than that across the Indo-Gangetic plain. So it is apparent that the crustal structures of the two regions are different. Taking the Indian plate boundary (Fig. 3) as the boundary between the two regions, the epicentral distance, $\triangle$, of the entire path can be written as, $\triangle = \triangle_1 + \triangle_2$, where $\triangle_1$, is the distance along the part of the wave path in the Indo-Gangetic plain and $\triangle_2$ is the distance along the path in central Myanmar (Burma). The group velocity U_2 across central Burma (Myanmar) is obtained by:

$$U_2 = \triangle_2 \Big/ \left(\frac{\triangle}{U} - \frac{\triangle_1}{U_1}\right)$$

where, U_1 is group velocity across the Indo-Gangetic plain shown by continuous curves in Figs. 4 (a & b). The group velocity U_2 across central Myanmar (Burma) thus obtained is shown in Figs. 5 (a & b).

The data of both Rayleigh and Love waves do not lie along a smooth curve apparently because of complex lateral variation in central Myanmar (Burma). However, we have assumed a laterally homogeneous structure in order to evaluate an average crustal structure. A trial and error method was applied to fit the data with theoretical dispersion curves for a laterally homogeneous structure. The crust and subcrustal model obtained in this way is given in Table 2 and its theoretical dispersion curves are shown in Figs. 5 (a & b). The Figs. 5 (a & b) show that the theoretical curves fit the observed data, but the fit is not very good. However, remembering the complexity of the crust of central Myanmar (Burma), the model (Table 2) may be considered as an average estimate of the crust for this region.

TABLE 1

Parameters of earthquakes used in this study

S. No.	Date Y	M	D	Time hr	min	s	Epicentre Lat. (°N)	Long. (°E)	Depth (km)	Mag.	Epc. dist. (km)
1	1980	Jul	29	12	23	07.7	29.34	81.21	3	5.7	2144
2	1980	Jul	29	14	58	41.6	29.63	81.09	23	6.1	2169

TABLE 2

Crustal and subscrustal structure of central Myanmar (Burma)

Layer No.	Thickness (km)	Depth of top (km)	P-wave vel. (km/s)	S-wave vel. (km/s)	Density (gm/cm³)
1	8	0	5.20	3.05	2.40
2	8	8	4.40	2.55	2.00
3	9	16	5.64	3.45	2.50
4	30	25	6.60	3.96	2.74
5	∞	55	7.65	4.50	3.08

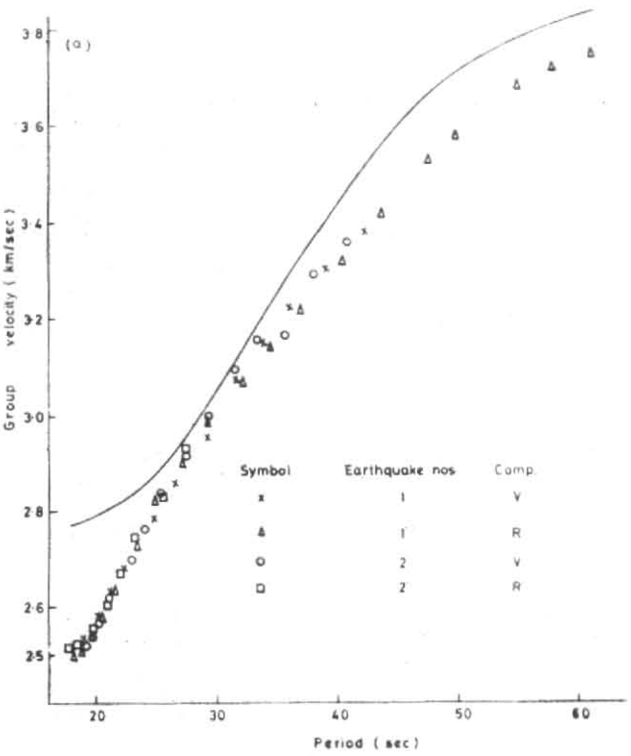


Fig. 4(a). Rayleigh wave group velocity data for the whole wave path

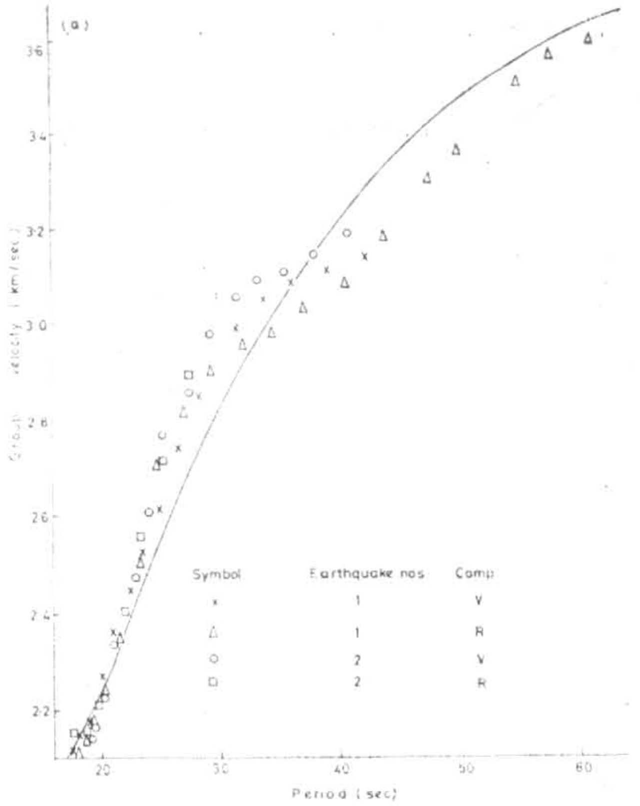


Fig. 5(a). Rayleigh wave group velocity across central Myanmar (Burma)

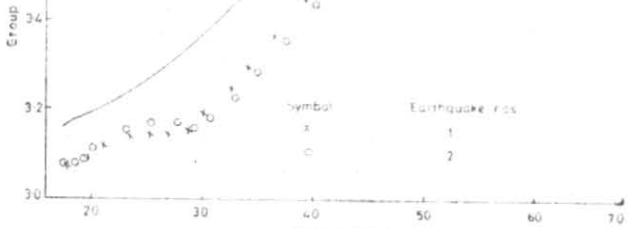
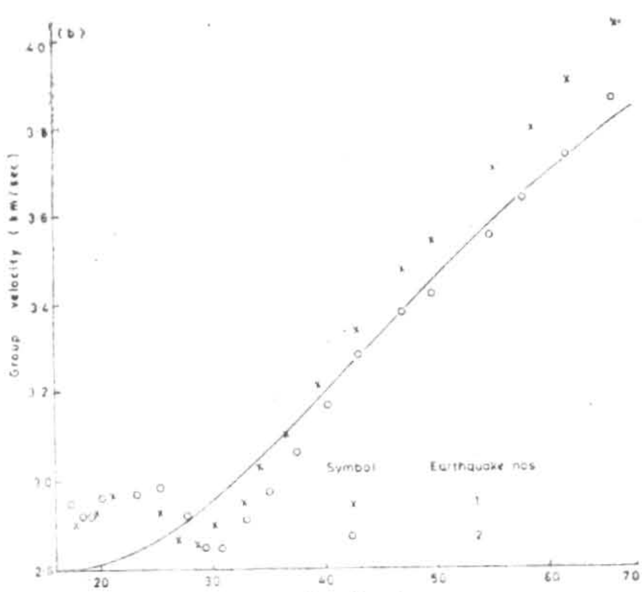


Fig. 4(b). Love wave group velocity data for the whole wave path



Figs. 5(b). Love wave group velocity across central Myanmar (Burma)

4. Discussions

The crust of central Myanmar (Burma) (Table 2) shows two thick sedimentary layers with a total thickness of 16 km. The top sedimentary layer has abnormally high velocities. It is known that a north-south line of volcanic rocks pass through the middle of the central lowlands. This volcanic line is marked by discontinuous outcrops of essentially andesitic but locally basaltic and rhyolitic volcanic rocks, interbedded with fluvial sediments (Chibber 1934). The eastern highlands also show volcanic rock in Mesozoic sediments (Mitchell 1981). Further the western part of Indo-Burman ranges are comprised of Cretaceous to Eocene sedimentary rocks and the eastern part consists of schists and Ladinian to Carnian turbidites (Gramman 1974) overthrust by serpentinized harzburgites and locally by pillow lavas and hornblende gabbros (Mitchell 1981). These high velocity rocks near surface in many areas of central Myanmar (Burma) give rise to the high velocity in the top sedimentary layer. The second sedimentary layer forms the low velocity layer in the crust.

In the central lowlands, molasse sedimentation began in Eocene time in the western part and more recently in the eastern part. Most of the infilling has occurred since late Oligocene or early Miocene time under deltaic and fluvial conditions. Rodolfo (1969) noted that in the southeastern part the total thickness of Tertiary and Quarternary sediments could be in excess of 10 km; according to Mitchell and Mckerrow (1975) the central lowland contain up to 17 km of Tertiary and fluvial sediments. The thickness of sediments obtained here is consistent with these results. Curray *et al.* (1978) report that marine seismic refraction profiles suggest such a thickness and suggest that the continental shelf sediments near the Irrawaddy delta are underlain by oceanic crust continuous with Andaman basin. Although relatively thin granitic layer in the obtained model (Table 2) partially supports this type crust but thick basaltic layer has been obtained in the present investigation. The total crustal thickness of central Myanmar (Burma) is found to be 55 km. The group velocity data of Chaudhury (1966) across Indo-Gangetic plain are shown by continuous lines in Figs. 4(a & b); inversion of these data gives a crustal thickness of 43 km for Indo-Gangetic plain (Chun and Yoshi 1977). Thus the crustal thickness increases in central Myanmar (Burma). The western Myanmar (Burma)—Shan plateau (of Asian plate) collision probably occurred during mid-Mesozoic (Mitchell 1981). This relatively old plate boundary at present is termed as the Sagaing fault where right lateral strike slip is occurring now. Further Indo-Burman ranges in west of central Myanmar (Burma) formed during subduction of the Indian plate since cenozoic period. The inferred thick crust of central Myamnar (Burma) may be explained by the existence of an old and new convergent plate boundaries on two sides of this region.

5. Conclusions

(*i*) Average crustal and subcrustal model for central Myanmar (Burma) is given in Table 2.

(*ii*) The model shows two sedimentary layers each of 8 km thickness. Presence of volcanic and other high velocity rocks in the top sedimentary layer gives rise to abnormally high velocity for this sedimentary layer. The lower sedimentary layer forms the low velocity zone of the crust.

(*iii*) The relatively thin granitic layer shows oceanic type of crust for this region. However, presence of thick basaltic layer cause a total crustal thickness of 55 km. The thick crust under central Myanmar (Burma) apparently arises because this region is bounded by relatively old and new converging plate boundaries.

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