Comparison of the deep crustal structure and seismicity of North America with the Indian subcontinent

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We summarize geophysical information from North America and India, and find many similarities in the deep crustal structure of the two continents. From this, we infer that similar processes have operated, particularly in the accretion and stabilization of the cratonic regions. Seismic images and other data suggest that plate tectonic processes have been active, both in the North American and Indian shields, since the late Archean. Precambrian orogens and high-pressure granulite terrains of both regions have developed nearly identically through time since about 2500 Ma. Such similarities invite direct comparisons of deep crustal structure. Here we present results from work in North America including: maps of crustal thickness, maps of average *P*-wave velocity of the crystalline crust, maps of average P_n (sub-Moho) velocity, and statistical analysis of crustal properties.

THE seismic structure of the crust and upper mantle provides critical information regarding the composition and evolution of the lithosphere. Studies have been conducted on a global basis in a wide range of geologic and tectonic environments. These environments include: shields, platforms, orogens, rifts, and highly-extended crust. These studies have aided our understanding of the geologic and tectonic processes responsible for the evolution of the crust[1–4]. In addition, seismic profiles can reveal much along active crustal fault zones, where seismic hazard is high.

Until recently, past geophysical studies in India have been mainly confined to crustal investigations, and therefore this comparative review will focus on the crust. We summarize velocity–depth structure in different geological settings as deduced from refraction studies, but also to illustrate the finer structural variations depicted in the reflectivity character. In addition, we discuss the seismicity of the two continents.

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Geology and tectonics

North America

The core of the North American continent is composed of several Archean cratons including the Superior, Slave, Nain, Hearne, Wyoming and Rae (Figure 1). These cratons were welded together during Paleoproterozoic collisions and have been coherent since 1.7 Ga[5]. Plate tectonic processes, believed to have been active since the Archean, have dictated the evolution of this continent. The present-day continental boundaries evolved during the Paleozoic era, and the two main Paleozoic features of the continent are the western Cordillera and the Appalachian fold belt in the west and east respectively.

The oldest rocks within the present-day Western Cordillera are Precambrian, and the Cordillera now extends from Mexico to Alaska[6] (Figure 1). The Archean and Proterozoic rocks of the Cordillera were truncated by late Proterozoic rifts (related to the break-up of a late Proterozoic supercontinent), which formed a carbonate-dominated stable continental margin lasting from the Cambrian to the Early Carboniferous. This margin has been active since 300 Ma, first with a series of accretions that formed such structures as the Sierra Nevada mountains, and then since 25 Ma with the extension that formed the Basin and Range Province[6].

The Appalachian fold belt of eastern North America consists of the eroded core of a Paleozoic mountain chain that extends some 3000 km from the southeastern United States to Newfoundland (Figure 1). The Appalachian mountains also contain a record of a number of arc–continent, and continent–continent collisions, as well as numerous rifting events[7].

India

The Indian subcontinent is a mosaic of several Archean cratonic blocks including the Dharwar, Bhandara, Singhbum, Southern Granulites, Bundelkhand and Mewar crustal[8,9] (Figure 2). The Indian Shield has evolved as a result of the interaction of these crustal blocks which are separated

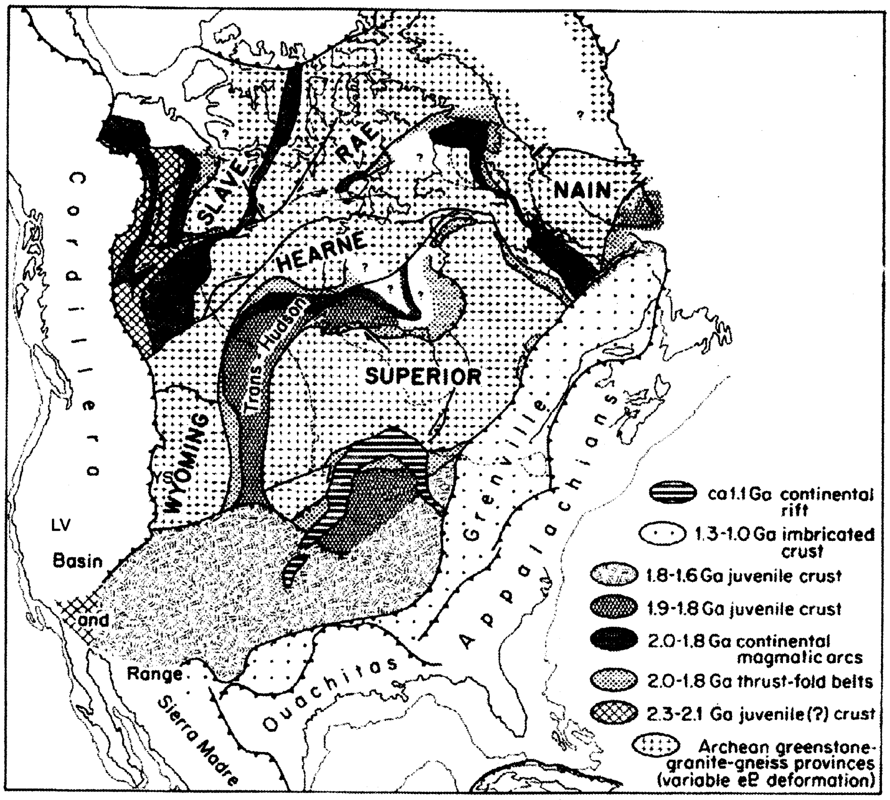

Figure 1. Generalized map of the cratons and major structural features of North America (after Hoffman[5]). YS, Yellowstone; LV, Long Valley. Ages of formation are given in the key at right.

by rifts, suture zones, and fold belts. Several of these suture zones have been reactivated during various geological periods since the Proterozoic. The Aravalli, Satpura, Delhi and Eastern Ghats are the important Paleo-Mesoproterozoic fold belts of the Indian shield.

The Indian subcontinent is primarily made up of Precambrian rocks. The Dharwar craton (3400 Ma) is a typical Archean greenstone-granite-gneissic terrain as observed elsewhere in the world. The Narmada–Son lineament (NSL) is the dividing line between the northern and southern cratons, and extends to a distance of 1600 km in the NE–SW direction, from the west coast to the northeastern margin of the Indian Shield. It is regarded as a Paleoproterozoic plate boundary which reactivated as a rift during subsequent periods. The less deformed intra-cratonic Vindhyan, Cuddapah, Chattisgarh and Bastar basins are formed during Mesoproterozoic period at the paleo-plate boundaries (Figure 2).

The Indian continent was a part of Gondwanaland during the Paleozoic era. Present-day continental margins are formed during the Mesozoic rifting in the east and west with the separation of Australia, Antarctica and Africa/Madagascar during 130–80 Ma period. The Himalayan mountains are evolved during the Eocene by the collision of the Indian plate with the Eurasia.

Petroliferous basins from the Mesozoic to the present are situated in between cratons and also along the continental margins. Some of these basins are covered with younger flood basalts. The Crozet/Kergulean hotspot (115 Ma) in the east and the Reunion hotspot (66 Ma) in the west also influenced the evolution of the continent, resulting in the extrusion of the Rajmahal and Deccan flood basalts which now cover ~20% of the surface of the Indian subcontinent (Figure 2).

Comparison of seismicity patterns

Earthquakes are one of the primary indicators of present-day plate boundaries. The western margin of the North American plate is clearly identified by the presence of earthquakes (Figure 3). Likewise, the present northern plate boundary of the Indian shield (Himalayan ranges) is also clearly identified by seismicity (Figure 3). Intracontinental seismicity observed in the Indian shield along the mobile belts (Figure 2) indicates the locations of paleo-plate boundaries (sutures) as well. These paleo-boundaries have deep-seated faults which are being reactivated due to stress accumulation. Eighty per cent of intraplate earthquakes occur at these paleo-plate boundaries[10]. Many of these paleo–plate boundaries also exhibit high heat flow which raises the brittle-ductile transition.

The seismicity associated with the Narmada–Son lineament (NSL; Figure 2) includes the Jabalpur earthquakes (21 May

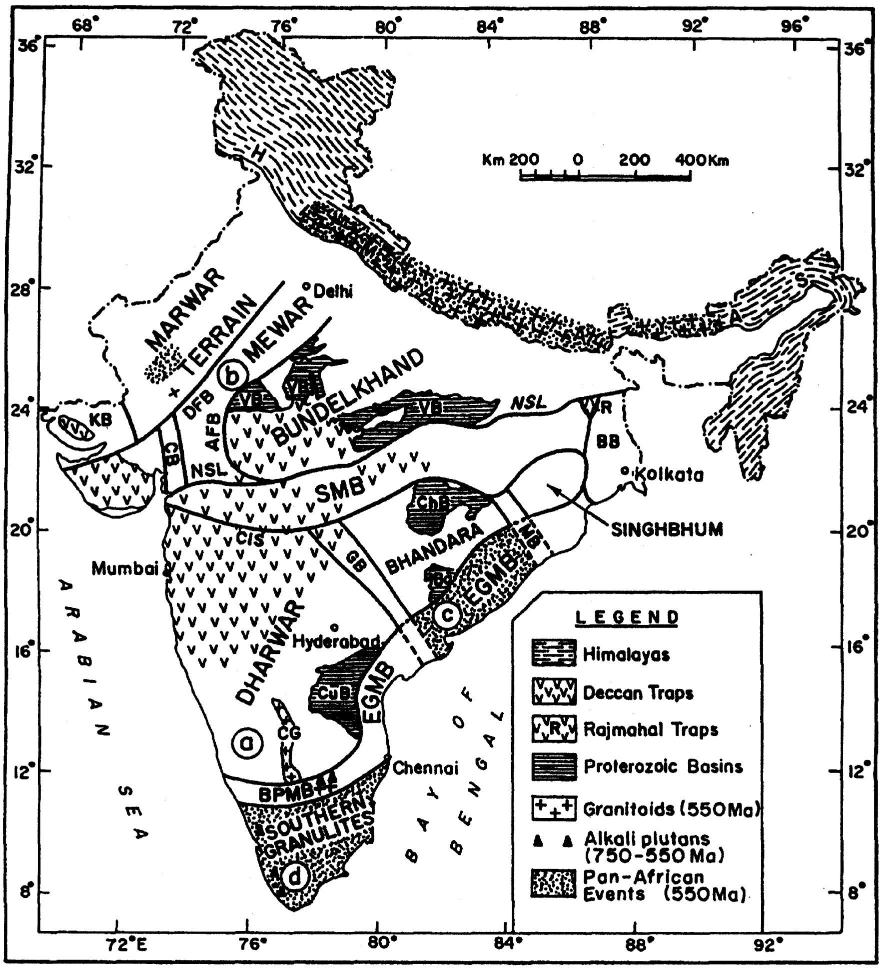

Figure 2. Generalized tectonic map of India. Abbreviations are, Early-late Proterozoic fold belts: AFB, Aravalli Fold Belt; DFB, Delhi Fold Belt; SMB, Satpura Mobile Belt; EGMB, Eastern Ghat Mobile Belt; BPMB, Bhavani Palghat Mobile Belt; NSL, Narmada Son Lineament; CIS, Central Indian Suture. Proterozoic Basins: CuB, Cuddapah Basin; Ba, Bastar Basin; ChB, Chattisgarh Basin; VB, Vindhyan Basin. Phanerozoic Basins: GB, Godavari Basin; MB, Mahanadi Basin; BB, Bengal Basin; CB, Cambay Basin; KB, Kutch Basin. Metamorphic activities: a, 2500 Ma ; b, 1800 Ma, c, 1100 Ma; d, 550 Ma.

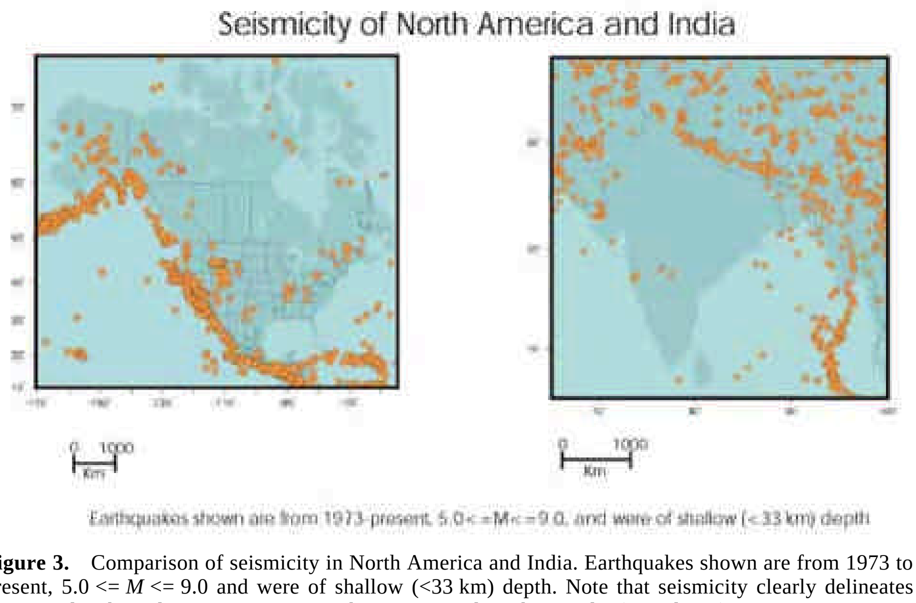

Figure 3. Comparison of seismicity in North America and India. Earthquakes shown are from 1973 to present, 5.0 <= M <= 9.0 and were of shallow (<33 km) depth. Note that seismicity clearly delineates tectonic plate boundaries in western North America and northern India (Himalayas).

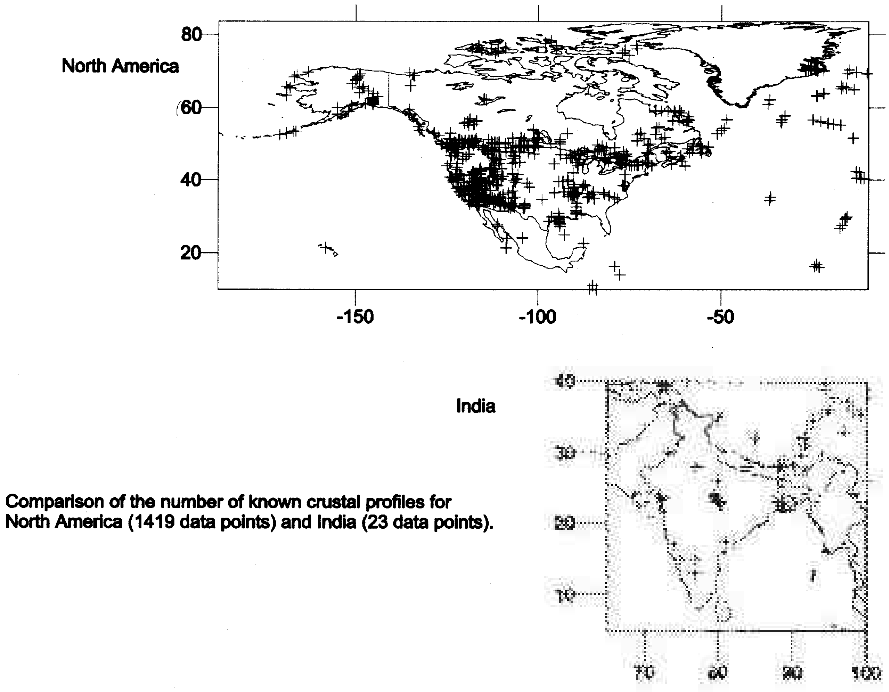

Figure 4. Comparison of available crustal structure data for North America and India. In regions where data density is poor, extrapolation techniques are used to infer crustal properties. Also, one can infer properties of the crust in data-poor regions that are of similar tectonic origin to other, better-studied areas.

1997, $M = 6.0$ and 17 May 1903, $M = 6.0$), the Son-valley earthquake (2 June 1927, $M = 8.5$) and the Satpura earthquake (14 March 1938, $M = 6.2$). These events could be attributed to reactivation of faults situated at the edges of different sub-blocks located all along the 1600 km lineament. Other seismic zones are associated with mega-shear zones located along the Eastern Ghat mobile belt (e.g. the Ongole earthquakes, 12 October 1959, $M = 6.0$, and 27 March 1967, $M = 5.4$) and western part of the Indian shield.

In addition, the 26 January 2001 $M = 7.2$ Bhuj earthquake in Gujarat province, India may be compared to the 1811–1812 $M \sim 8.0$ earthquakes of the New Madrid Area, North America[11]. These events were all intracontinental, and not associated with plate boundary events. In Gujarat, the earthquake was possibly related to the hotspot track responsible for the formation of the Deccan Traps. The New Madrid Seismic Zone, however, is thought to be associated with a failed rift through the North American continent dating from the late Precambrian and/or early Paleozoic[12]. No hotspots are associated with the New Madrid seismicity.

Seismic data, analysis, and main features of continental crustal structure

Seismic methods have been used extensively for determining the structure of the crust and upper mantle. We concentrate here on those crustal and uppermost mantle studies that have utilized controlled-source seismic refraction and deep crustal reflection data[13,14]. The main advantages of such studies are: (i) the exact time and position of the seismic sources are accurately known; (ii) there is no reliance on passive (earthquake) sources that may occur infrequently and/or have an unsuitable spatial distribution; (iii) the recording geometry of the seismic investigation may be planned in relation to the specific geologic or geophysical target.

Crustal reflection studies in the near-vertical range produce the highest resolution geophysical images of the crust and upper mantle[15–17]. The seismic properties most readily obtained from reflection profiles are reflectivity patterns which correlate with distinct geologic settings[2]. An additional feature of reflection studies is that the frequencies of reflected signals are higher compared to refracted waves, and thereby provide better resolution. In contrast, vertical reflections do not provide velocity information for the deep crust unless extremely long spreads are used.

Seismic velocity distributions and crustal thickness values vary widely in different geological settings, however if enough data is collected, an extrapolation is possible to other regions of the Earth, and a comprehensive model may be produced. A program of assembling globally all seismic survey results in the format of localized one-dimensional velocity–depth functions is currently underway at the US Geological Survey (USGS) in Menlo Park, CA, USA. The details are described in ref. 18. Figure 4 shows some of the present-availability of data from North America and

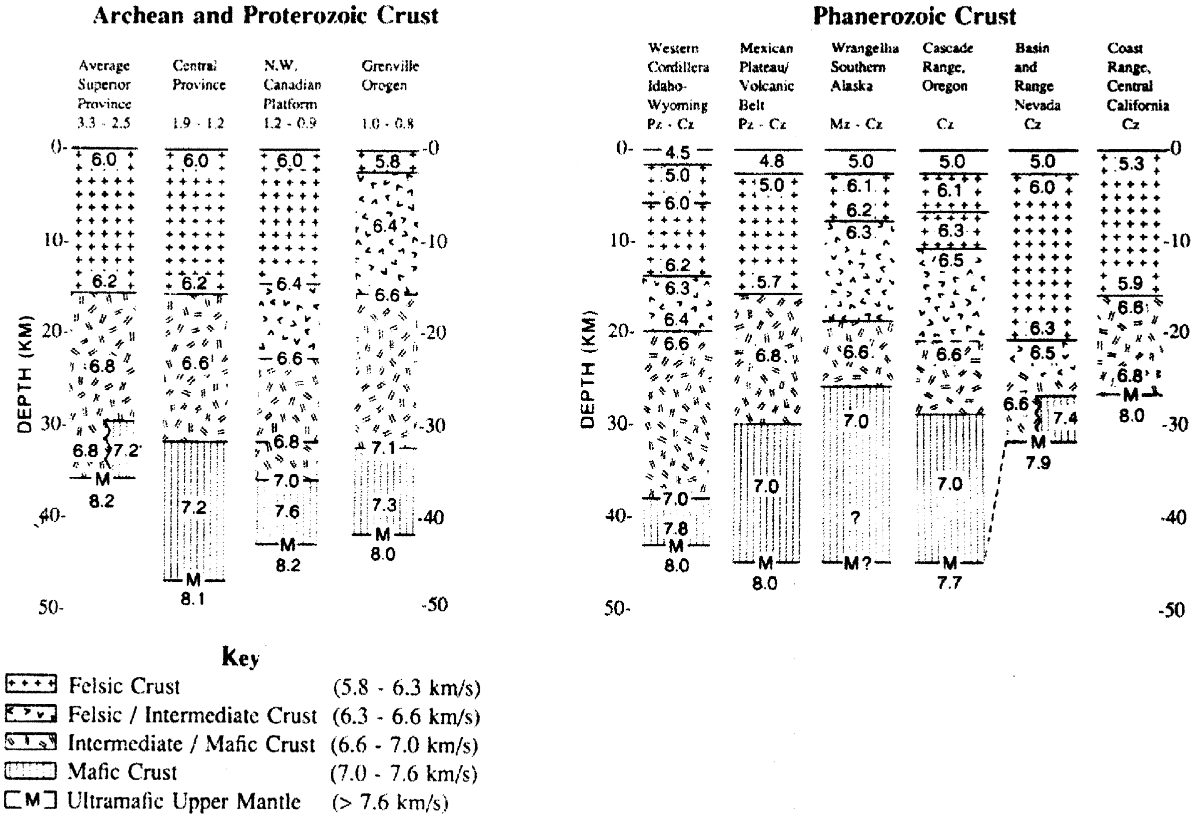

Figure 5. Seismic velocity–depth models of various regions in the North America (after Mooney and Braile[26]).

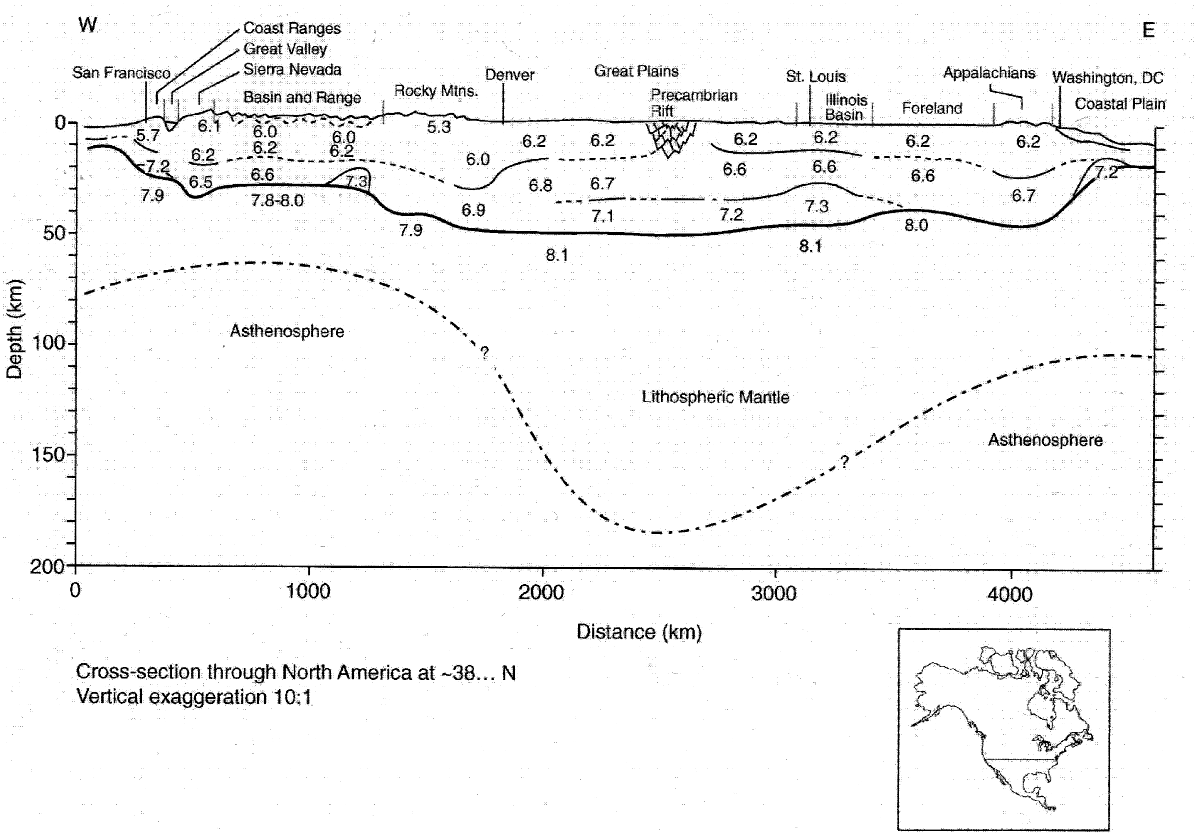

Figure 6. Generalized crustal cross section through North America at 38° North.

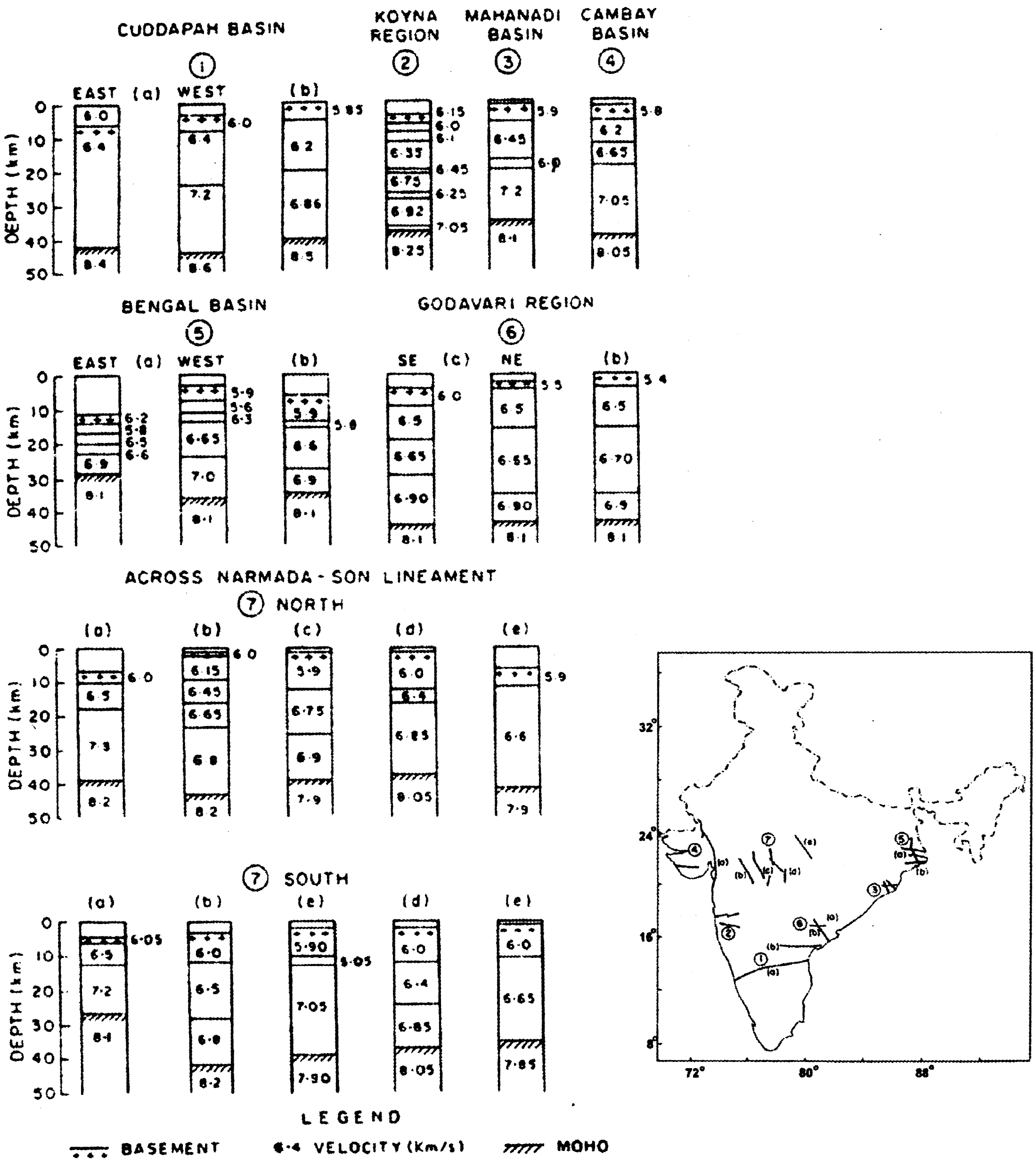

Figure 7. Seismic velocity–depth models of various regions of the Indian sub-continent (from Reddy *et al.*[4]).

from India. Numerous additional seismic surveys have been conducted in India to those shown on Figure 4, however, for our purposes, we mainly limit our interest to results published in international journals.

Seismic velocity models of the crust generally consist of two or more layers separated by velocity discontinuities or steep gradients. In relatively stable continental regions the thickness of the crust, as defined by depth to Moho, is between 30 and 50 km. The seismic velocity in the upper crustal layer (basement) is usually 5.6–6.3 km/s, and increases to 6.4–6.6 km/s at a depth of 10–15 km. In many stable continental interiors, there is a third crustal layer with a velocity of 6.8–7.2 km/s. The upper mantle velocity (P_n) below the Moho is typically about 8.0–8.1 km/s, but varies from 7.6–8.5 km/s.

Summary of existing data

North America

The deep structure of the North American lithosphere has been the subject of intense investigation since the pioneering work of Tatel and Tuve[19] at the Carnegie Institution of Washington. Several summaries of the crustal structure of North America have been published over the past forty years[20–27]. Velocity–depth models for important tectonic regions are presented in Figure 5. A generalized cross-section across the United States is shown in Figure 6. Canadian researchers have also published a great deal on crustal structure over the past fifteen years under the LITHOPROBE Program[16,17]. These investigators have used coincident

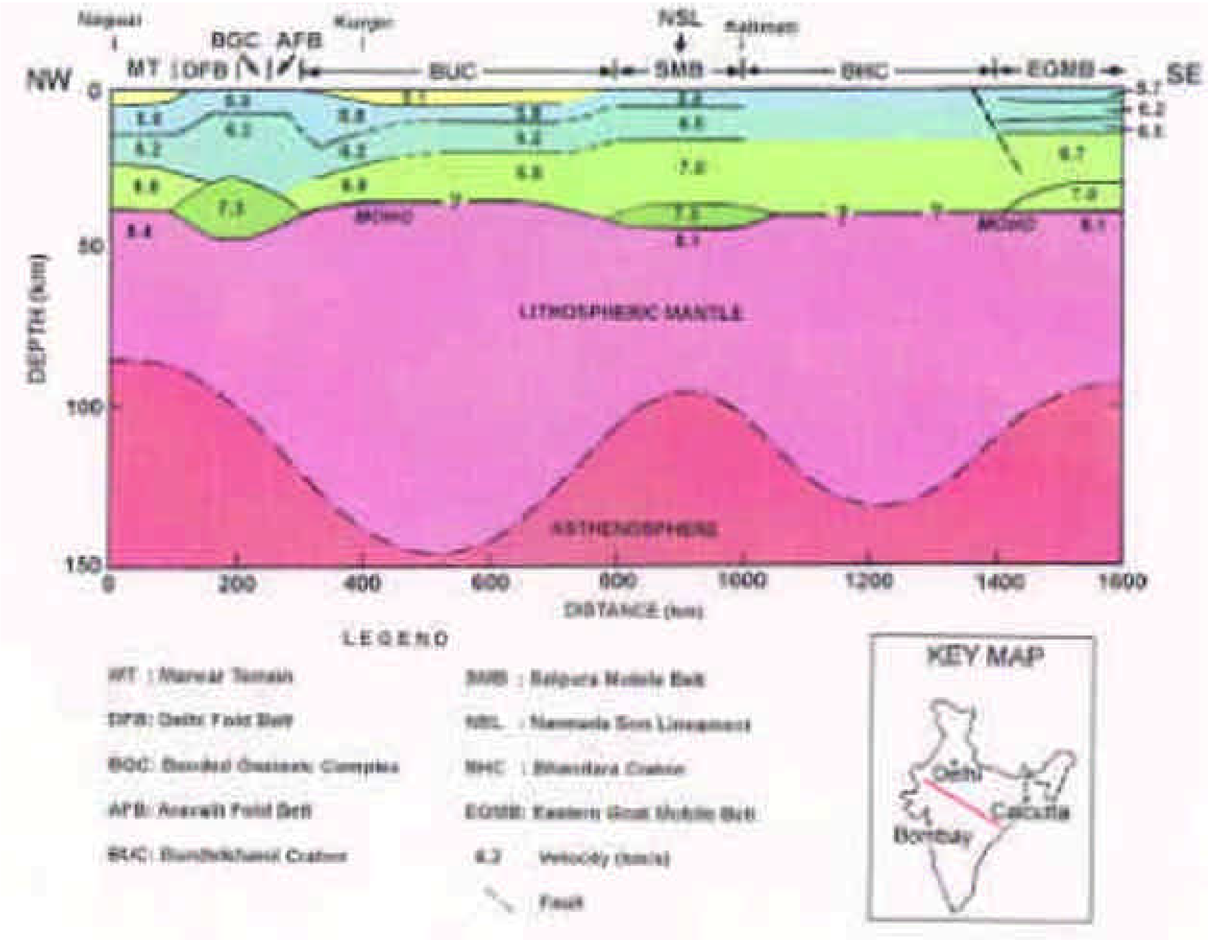

Figure 8. Cross-section through the Indian Shield at 28°N, 72°E to 18°N, 84°E. Vertical exaggeration is 2 : 1 (From Mooney *et al.*[44]).

seismic reflection and refraction studies to obtain higher-resolution data than previously possible.

India

Crustal seismic studies in India began in 1972. Twenty DSS profiles have been conducted totaling more than 6000 km. Long-range refraction and wide-angle reflection techniques with a dense detector spacing of 80–200 m and shot point interval of 10–40 km were used to acquire these data. Kaila and Krishna[3] , Mahadevan[28] and Reddy *et al.*[4] have provided reviews of the Indian continental crustal structure. Measurements of crustal thickness fall into the range of 35–40 km (Figure 7), with the biggest exception being the Himalayas which are known to have thicknesses up to 80 km[28].

A series of representative velocity–depth models for the Indian subcontinent are shown in Figure 7. The use of seismic reflection data and well-constrained velocity–depth profiles allows the creation of two-dimensional profiles across the Indian subcontinent. An example is shown in Figure 8. The Moho depth is seen to be around 38 km, and we note several lenses of 7.3 km/s velocity across the subcontinent. Also, the transition from the lithospheric to the asthenospheric mantle fluctuates by about 50 km across the profile.

Discussion

A comparison of the deep structure and seismicity of North America and India presents interesting observations, as these continents have had a similar geologic history since 3500 Ma. We begin with some general comments before making specific comparisons below.

Extensional and compressional forces play a major role in determining the structure of the crust and mantle lithosphere. The thickest crust is generally observed beneath mountain belts, whereas thinner crust is generally found beneath highly-extended crust and at continental margins. However, some mountain belts such as the Rocky Mountains and the Appalachians have undergone post–collisional extensional collapse that has reduced crustal thickness. Phanerozoic mountain belts are absent in India (excepting the Himalaya), so a comparison cannot be made. However, the Proterozoic crust of the Trans-Hudson orogenic region

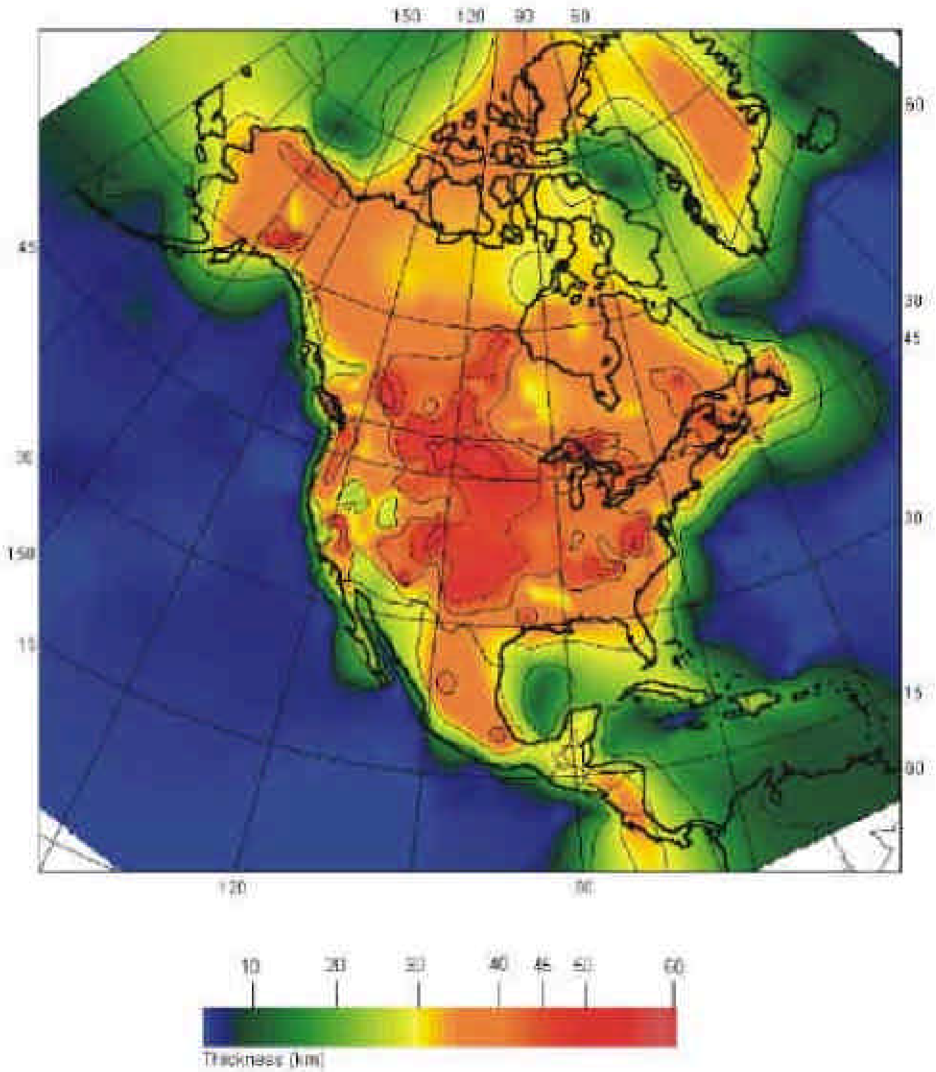

Figure 9. Contour map of crustal thickness, H_c, under North America and the surrounding ocean basins. The average thickness of the continental crust, including the continental margins, is 36.7 km, with a standard deviation (s.d.) of 8.4 km.

of North America (Figure 1), and the Aravalli Delhi mobile belt of India (Figure 2) still retain their crustal roots[2,29,30].

Both compressional and extensional tectonic regimes have been imaged by seismic reflection studies. These results indicate that oppositely-dipping reflections are typical for collisional orogenies, interpreted as deeply-penetrating crustal-scale fault zones representing subduction/suture zones. In contrast, a horizontal reflection fabric usually corresponds to extended crust, such as the Basin and Range province, North America[2] (Figure 1).

Many tectonic domains of North America and India show similar characteristics. These include: reflectivity patterns, crustal velocity structure, crustal thickness, history of metamorphism, and timing of formation. The mechanisms for evolution of similar tectonic domains seem to be comparable. A normal crustal thickness of 36–40 km seems to be common for both regions when a mafic lower crust is present in an area of predominantly Proterozoic age. Phanerozoic basins have a crustal thickness of ~30 km, with some exceptions.

Volcanic plateaus, such as the Columbia, Deccan and Chota Nagpur plateaus are associated with basaltic volcanism. The Columbia flood basalts of North America, and the Deccan and Rajmahal basalts of India are found to be related to the Yellowstone, Reunion and Kerguelan hotspots, respectively. These hotspots are, in turn, related to the epeirogenic uplift of these regions.

Granulite facies metamorphic activities are observed around 2500 Ma at the boundary of the Dharwar craton; 1750 Ma, in the NW Indian shield in the Aravalli Delhi fold belt region; 1100 Ma, in the Eastern Ghat region; and 550 Ma, in the southernmost part of India (Figure 2).

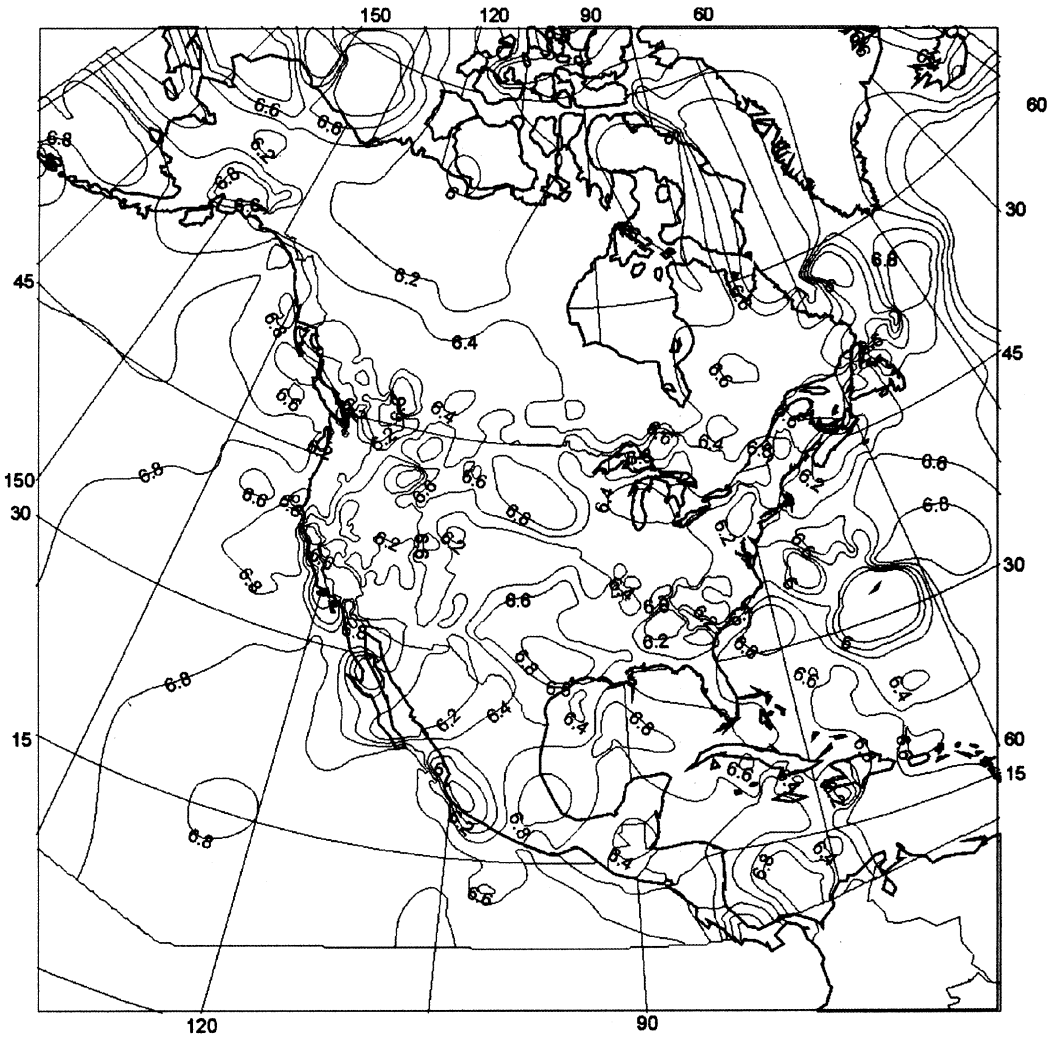

Figure 10. Contour map of P_{cc}, the average *P*-wave velocity of the consolidated (crystalline) crust. The P_{cc} velocity differs from P_c (Figure 11) in that surficial sediments (in fact, velocities <5.8 km/s) are excluded from the calculation. The average velocity on continental crust is 6.45 km/s; on oceanic crust it is 6.61 km/s. These averages confirm the well-known fact that the crystalline oceanic crust is mafic (basaltic), whereas the continental crust is intermediate (equivalent to a diorite) (e.g., Christensen and Mooney[43]).

The orogenic and granulite facies metamorphic activity in the Indian shield is found to have occurred at approximately the same time as that of North America, and is likely related. Such an interrelationship is also observed in the North American continent. The Pan-African thermotectonic event at 550 Ma seems to be confined only to Gondwana continents. Hoffman[5] and Lucas *et al.*[31] have suggested that the Trans-Hudson orogeny was formed as a part of a world-wide network of Proterozoic orogenic belts associated with the amalgamation of Archean cratons. These events could have been related to the formation of a supercontinent ~1800 Ma.

Rogers[32] has suggested the presence of two supercontinents Rodinia and Pangaea around 1100 and 300 Ma respectively, and Condie[33] points out that continental crustal growth is episodic. Thus, a third supercontinent at ~1800–1900 Ma is likely to have existed. From the distribution of U/Pb zircon ages from juvenile continental crust, Condie[33] suggested three supercontinent episodes during 2700, 1900 and 1200 Ma, respectively. This evidence along with the tectonic activities observed both in the North American and Indian continental regions suggest that there were four supercontinents around 2500–2700, 1800–1900, 1100 and 300 Ma with a ~700 Ma Wilson Cycle periodicity. This would suggest that many similarities in the two continents resulted from processes active on a global scale.

Crustal and velocity structure of North America

The contour maps presented in Figures 9–11 were constructed using commercial software employing the natural-neighbour technique for gridding. Smoothing of contours has not been applied. Certain regions with very sparse data (e.g. parts of

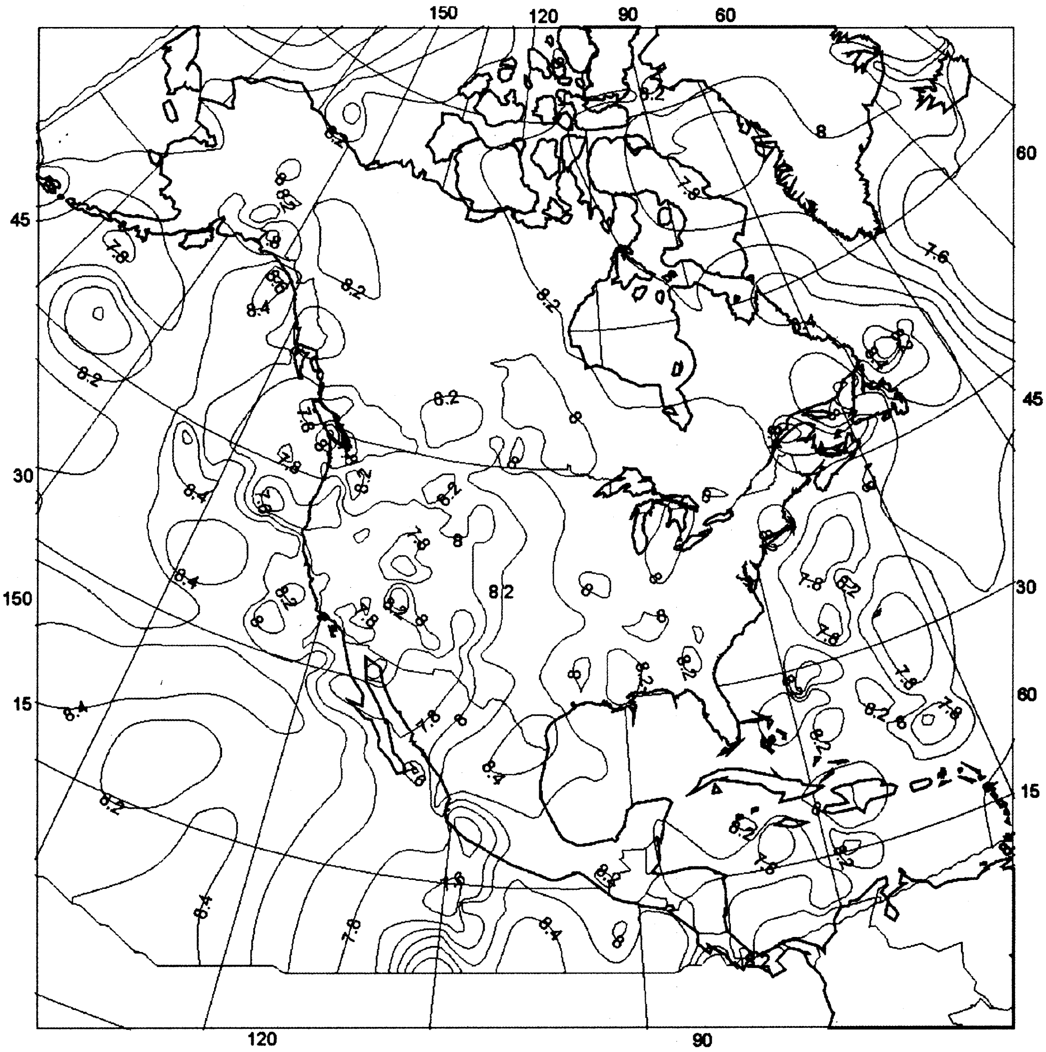

Figure 11. Contour map of sub-Moho *P*-wave velocity, P_n. The average velocity beneath continents and oceans are nearly equal (8.03 km/s and 8.06 km/s, respectively). There is a large contrast in values on either side of the Rocky Mountains: P_n values of 7.8 km/s are common to the west whereas values are >7.9 to the east. A roughly north-south zone of high (8.2 km/s) P_n velocity lies along the western edge of the Great Plains. Further east, lower values (~8.0 km/s) are typically measured.

Alaska, Baja California, Central America, the West Indies, and Greenland) yielded clearly erroneous contours. The contours in these regions were edited to avoid, for example, oceanic crustal thickness from appearing on continental crust. The raw data used are available at the Web address provided at the end of this article.

Crustal thickness (H_c)

Our map of the thickness of the crust under North America (Figure 9) indicates the following features. (i) Most of the crust under the Western Cordillera is thin (~ 30 km or less). This must result from the extension undergone by the region in the last 25 Ma. The exceptions are under the high mountains (Cascade, Sierra Nevada and Rocky Mountains). (ii) Thick crust (> 40 km) underlies the central region of the continent (Great Plains), as well as much of the Canadian Shield. This essentially corresponds to the Precambrian craton of North America ('Laurentia'). (iii) Relatively thick crust also underlies regions that have undergone compression some time during the Phanerozoic (Alaska and Brooks Ranges, Mexican Highland, Appalachian Mountains, high mountains of point (i)). (iv) The high density of data along both the east and west coasts of North America have allowed the contouring software to automatically reproduce these margins to correspond well to the width and locations of the actual continental shelves. The average thickness of the crust is 36.7 km, with a standard deviation of 8.4 km (Table 1).

Crystalline crustal *P*-wave velocity (P_{cc})

Regions with thick accumulations of low-velocity sediments strongly influence the contour map of whole-crustal *P*-wave velocity. Thus, we have also calculated the average *P*-wave

Table 1. Comparison of statistical analyses of Braile[36] (North America), Christensen and Mooney[43] (global), and Chulick and Mooney[27] (North America). H_c = crustal thickness; P_{cc} (S_{cc}) = average *P*-wave (*S*-wave) velocity of the crystalline crust (i.e. below sediments); P_n (S_n) = *P*-wave (*S*-wave) velocity of the uppermost mantle. n = number of data points; x = average value, $\pm s$ = standard deviation

		Braile[36]	Christensen and Mooney[43]	Chulick and Mooney[27] (continental crust only)	Chulick and Mooney[27] (all crust)
H_c (km):	n =	337	560	997	
	x =	36.10	39.17	36.72	
	$\pm s$ =	8.97	8.52	8.39	
P_{cc} (km/s):	n =	255	560	983	
	x =	6.435	6.45	6.456	
	$\pm s$ =	0.235	0.23	0.244	
P_n (km/s):	n =	320	560	906	1238
	x =	8.018	8.07	8.033	8.041
	$\pm s$ =	0.205	0.21	0.186	0.215

velocity in the crystalline crust (i.e. below surficial sediments, here taken as $V_p < 5.8$ km/s). The largest regions with high P_{cc} velocities (6.8 km/s) are within ocean basins (Figure 10). Exceptions are mentioned below. Continental crust generally has lower P_{cc} velocities (6.4–6.8 km/s). A close examination of Figure 10 reveals several important features. First, there are a number of continental regions of anomalously high (6.8 km/s) velocity. These include the Kapuskasing Uplift of southern Canada, where high-velocity lower crustal rocks have been thrust to shallow depth, the mafic volcanic crust of the Mid-Continental Rift (Figure 1), and Cambrian rifted crust of eastern Texas. There are also a number of regions with relatively low P_{cc} velocity, most notably the Western Cordillera. As previously noted, this is a region of recent extension and crustal thinning, and therefore has relatively high heat flow. Low P_{cc} also underlies portions of the southern Atlantic Coastal Plain and Appalachian Mountains.

Sub-Moho *P*-wave velocity (P_n)

The contour map of P_n, the seismic velocity of the uppermost mantle, is presented in Figure 11. Note that there is insufficient azimuthal coverage to make corrections for seismic anisotropy, which may amount to 2–6% in the uppermost mantle[34]. However, the following trends are evident from the map. First, regions of extension (i.e. East Pacific Rise and Western Cordillera), with thinned crust and/or high heat flow are delineated by low P_n. Second, high values (8.2 km/s) follow a north-to-south trend under the Great Plains. Third, lower values of ~ 8.0 km/s underlie the region just to the east of the Mississippi River, while somewhat higher values (> 8.1 km/s) lie to the southeast under the Appalachian Mountains and Gulf Coastal Plain.

As noted in ref. 27, this pattern is intermediate between that of James and Steinhart[35] and Braile[36]. Nonetheless, much of the continental interior is underlain by mantle with $P_n = 8.1 \pm 0.1$ km/s. We note that there are relatively few publications from North America reporting P_n greater than 8.3 km/s. However, P_n velocities as high as 8.6 km/s have been reliably determined in central Canada[37]. These high values were measured along the fast direction of a mantle with 4–5% seismic anisotropy. Thus, the P_n velocity structure of the continent warrants further analysis, especially with regards to a more thorough consideration of seismic anisotropy.

Crustal and velocity structure of India

Since only a portion of the available crustal structure data from India is presently incorporated in the USGS database, current contour maps of this region are crude by comparison to those for North America discussed above. Therefore, we will discuss trends apparent in the velocity–depth models presented in Figure 7, which are representative of all currently available data.

The crust of India is generally around 40 km thick. It is thickest along the east-central coast (~ 45 km, Godavari region), but thins considerably (to < 30 km) to the northeast along the eastern and southeastern flanks of the Mahanadi and Bengal Basins (Figure 2), respectively. This is probably due to a transition from continental to oceanic crust in these regions. Note that there is a similar thinning of the crust along the west coast under Kutch. The Cambay basin (Figure 2) is characterized by an upwarp of Moho during the late Cretaceous period, probably representing a transition-type crust marking a major source of the Deccan trap flows which have spread large distances in all directions.

Crystalline compressional wave velocities throughout India are relatively high (6.4–6.6 km/s), with little indication of recent intracratonic extension. Sub-moho compressional wave velocities under much of India are similar to those under much of North America (~ 8.1 km/s). Again, like North

America there are exceptions. Under central India, along the Narmada–Son Lineament, there is a region of low P_n (~ 7.9 km/s). In contrast, southern India is underlain by very high P_n velocities (~ 8.5 km/s, Cuddapah Basin).

The Archean Dharwar craton (Figure 2) has velocities of 5.9–6.4 km/s and 6.8–7.0 km/s for the upper and lower crust, and lacks a high velocity basal layer. The crustal thickness in the Dharwar craton averages 38 km, but significant local variations (thicker crust) have also been found. This is similar to the crustal structure of the Archean Superior province of North America[38] (Figure 1). One contrast between these two regions is that the southern part of the Dharwar craton has undergone granulite facies metamorphism during the 2500 Ma whereas the Superior province has not.

The Narmada–Son lineament (Figure 2) is the most conspicuous linear geological feature in the Indian Shield, after the Himalayas, and has played a significant role in the formation of a series of folded structures. This lineament cuts across central India in a NE–SW direction and has been periodically reactivated since the Precambrian. Results from five DSS profiles show variation of crustal thickness from 38 to 43 km across the lineament. A high velocity of 6.9 km/s at a shallow depth of ~ 10 km with a 7.3 km/s high velocity layer above the Moho are indicative of magmatic underplating in the region. Deep seismic reflection studies[39] have indicated the operation of collisional tectonics during the Proterozoic forming a suture between the Dharwar and Bundelkhand cratons (Figure 2). This collision is thought to be responsible for the presence of a high-velocity layer at shallow depth. The region has repeatedly undergone reactivation, and has witnessed seismic activity since the Proterozoic. The region is also associated with high heat flow.

Crustal reflection studies (under the Deep Continental Studies program) across the Paleo/Mesoproterozoic Aravalli Delhi Mobile Belt (Figure 2) in the northwestern Indian Shield have revealed deep-seated crustal scale thrust faults extending to the Moho and beyond. A thick, high velocity (7.3 km/s) lower crust is observed in this region[40]. Similar structures are also observed in the Trans-Hudson orogeny[31] (Figure 1) of the North American continent. This part of the Indian Shield witnessed two collisional episodes, the Aravalli and the Delhi during the Proterozoic at ~ 1800 and 1100 Ma which were contemporaneous with the Trans-Hudson and Grenvillean orogenies of the North America.

Seismic tomography and heat flow studies[41,42] over the Indian shield have indicated $a > 200$ km lithospheric thickness for the Archean Dharwar craton and lower thicknesses (80–100 km) for the Proterozoic mobile belts (e.g. Eastern Ghat, Aravalli Delhi, Satpura Mobile Belts). Some of these Proterozoic mobile belts have been affected by the separation of India from the rest of Gondwanaland, and also by the influx of Deccan flood basalts, processes that together span the past 115 Ma. The 80–100 km lithospheric thickness in these regions is comparable to the North American continental margins that were affected by extensional tectonics.

Conclusions

Seismic studies have been conducted in North America and India, providing valuable insight into the geologic and tectonic history of these two land masses. In this study, we provide evidence that plate tectonic processes have operated in a similar manner in both regions (e.g. the development of fold belts and rift basins) since the end of the Archean. Also, the deep structure of the crust (i.e. seismic velocities and crustal layer thicknesses) is found to be comparable, but varies widely depending on the local geology of each continent. Moreover, similarities in crustal structure between the two continents are likely to have been the result of global mechanisms, such as supercontinent formation and breakup, rifting, and intraplate magmatism.

The data that went into the North American portion of this study can be found online at: http://quake.wr.usgs.gov/research/structure/CrustalStructure/nam/index.html

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