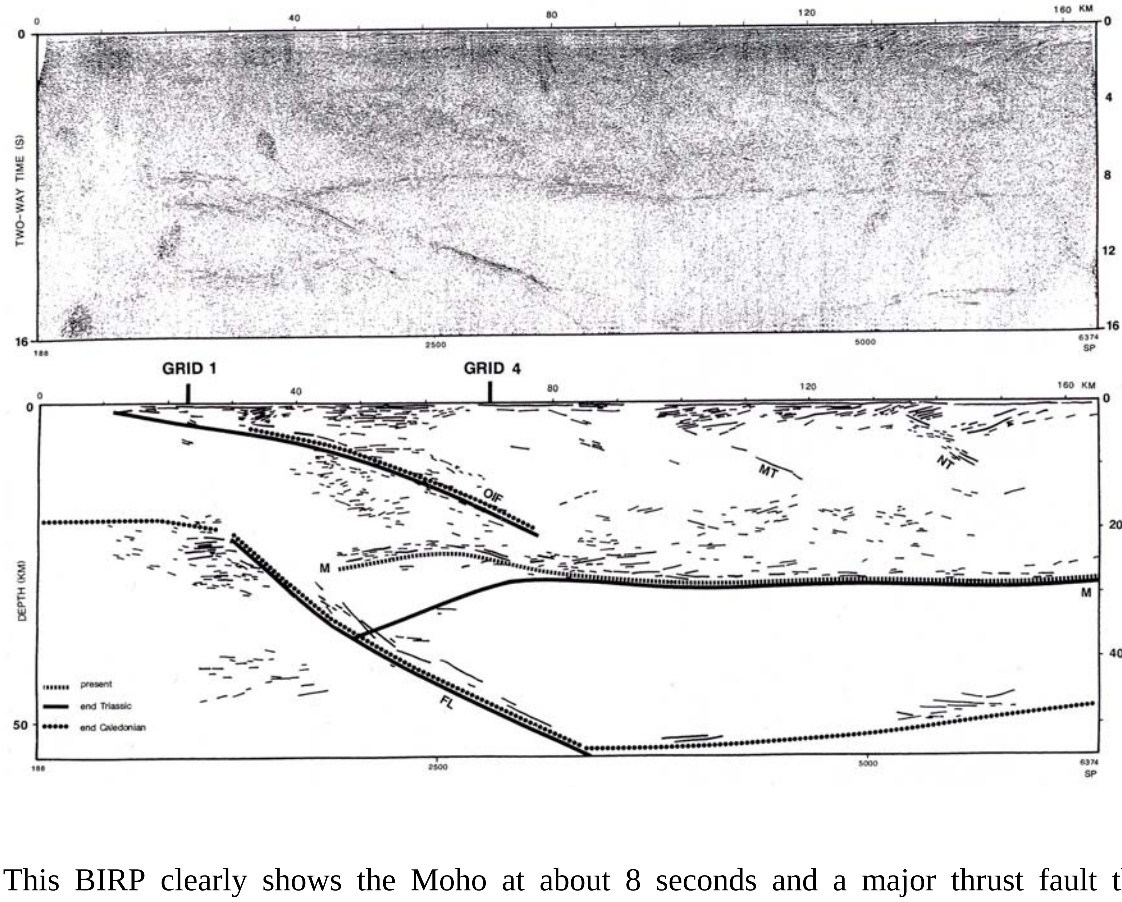
C2.10 Deep seismic reflection studies

In addition to their use in hydrocarbon exploration, seismic reflection studies can also be used to image the entire crust and upper mantle. A number of government and university research groups have made a number of deep seismic studies in recent years and improved our knowledge of the structure and evolution of the Earth.

2.10.1 BIRPS (British Institutions Reflection Profiling Syndicate)

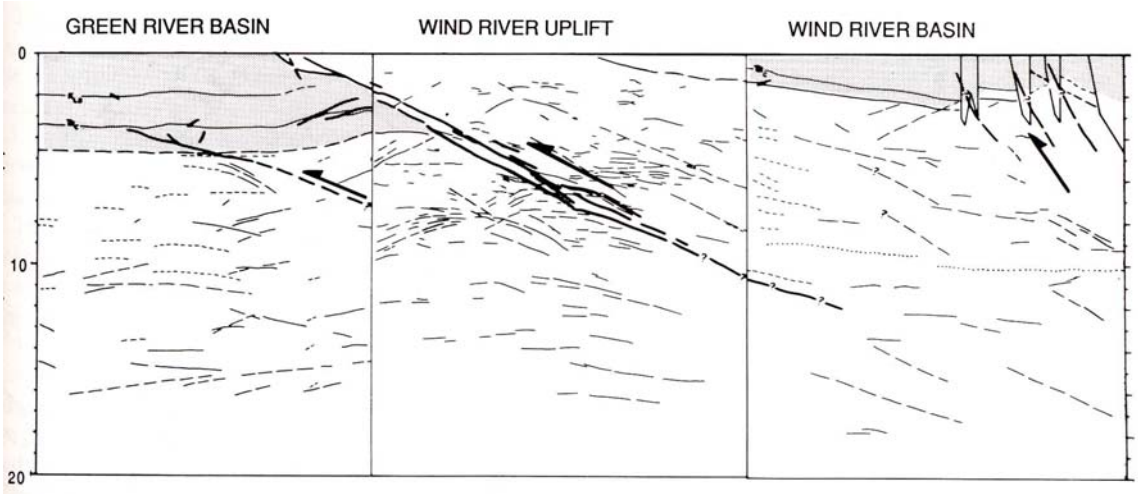
The first example is from the British Institutions Reflection Profiling Syndicate (BIRPS) and is shown in Kearey Figure 4.63. BIRPS collected most of their data with marine seismic surveys around Great Britain where the continental crust is present on the continental shelf. This reflection section is just like the sections collected for hydrocarbon exploration, except the recording time is longer (16 seconds). Collection of these data require a strong seismic source, typically a very large airgun array. Often more energy was used by the compressors than the ships engines. A very long seismic streamer was used to detect the normal move out in deep reflections. Some BIRPS surveys used to 2 ships to create a longer offset.



This BIRP clearly shows the Moho at about 8 seconds and a major thrust fault that apparently extends into the upper mantle. A common feature of many BIRPS profiles is significant seismic reflectivity in the lower crust. The origin of this feature is still not defined, but lenses of fluids, or mafic underplating are two possible explanations.

2.10.2 COCORP (Consortium for Continental Reflection Profiling)

The Consortium for Continental Reflection Profiling (COCORP) used land seismic data to study deep crustal structure in the United States.



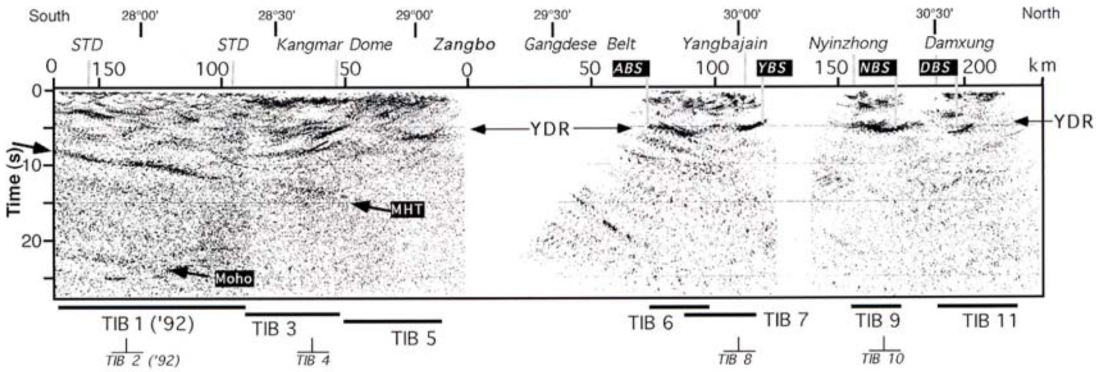
The figure above shows a seismic reflection image of the Wind River Thrust in Wyoming. This is a major feature associated with the Laramide orogeny (*Brewer et al*, 1980). Typical acquisition parameters for COCORP data were VIBROSEIS with a 96-fold CMP stack, recorder spacing of 100 m and spread length of 9.6 km. The VIBROSEIS signal was 8-32 Hz and at each location was stacked up to 80 times.

2.10.3 INDEPTH (International Deep profiling of Tibet and the Himalaya)

By the early 1990's COCORP had examined the crustal structure of many regions of the United States. This included old orogenic belts such as the study above, and active features such as the San Andreas Fault and Basin and Range province. However not all tectonic processes are currently active in the United States and they began to look overseas to places where certain tectonic processes are active today.

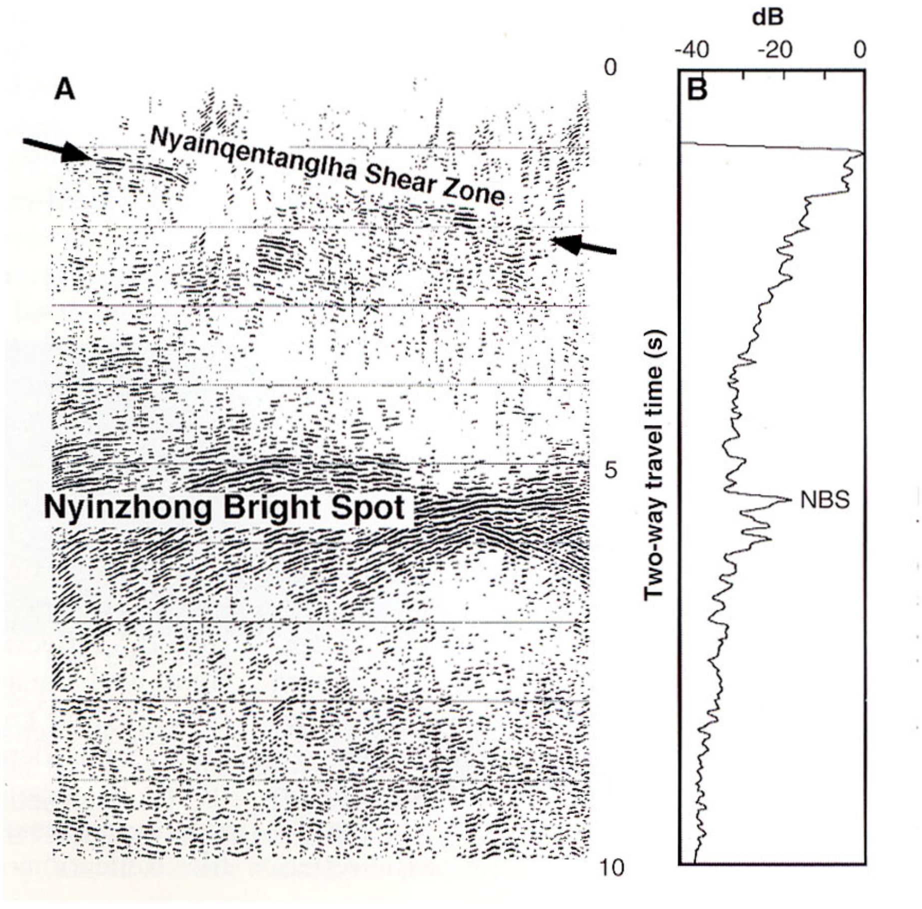
Interest in continent-continent collisions led to the INDEPTH project in Tibet. This used a Chinese seismic crew to collect seismic reflection and refraction data on a profile that crossed the Himalaya at 27.5º N and extended north onto the Tibetan Plateau. The primary energy source was explosives.



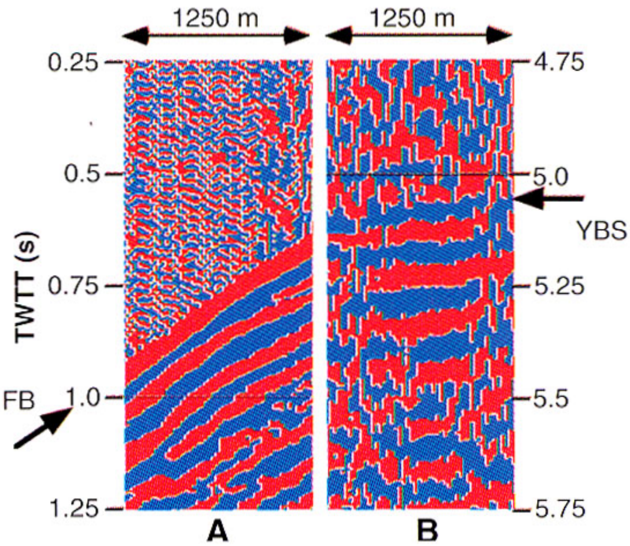


These seismic data imaged the Indian Plate being thrust beneath the Himalaya. The Main Himalayan Thrust (MHT) is the top of the Indian Plate. Note also that the Moho in the Indian Plate can be seen at a two-way travel time of 25 seconds. This observation showed that the 80 km thick crust was made by **stacking** Asian and Indian crust on top of each other (*Nelson et al*, 1996).

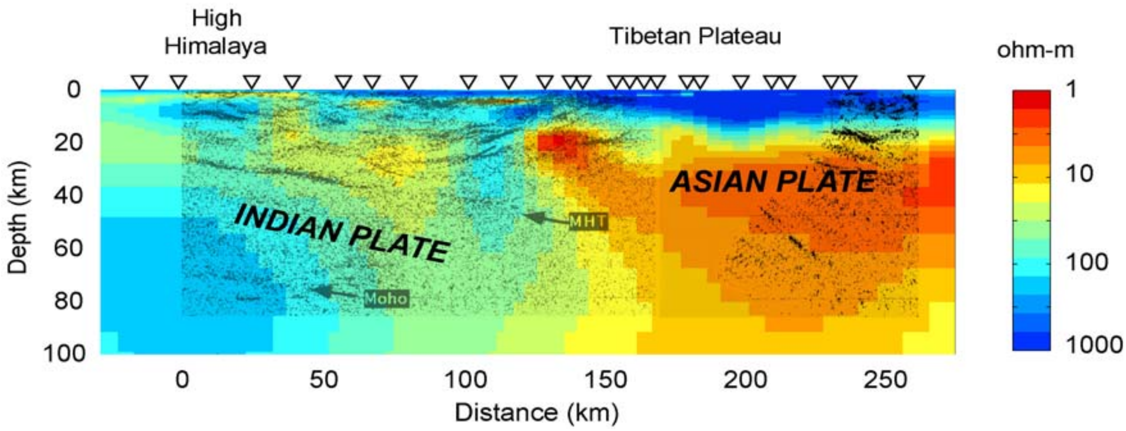
Another key observation from INDEPTH was that **bright spots** were observed beneath the Tibetan Plateau extending north from 29.75º N. These have a high amplitude and **negative polarity**, and may represent a thin layer of fluids.



Panel on the below shows how the polarity of the reflection (YBS) is determined by comparison with the first break (FB) of the direct P-wave. Since explosives were used as a source, it is known that the signal has a compression as the first arrival (*Brown et al.*, 1996).

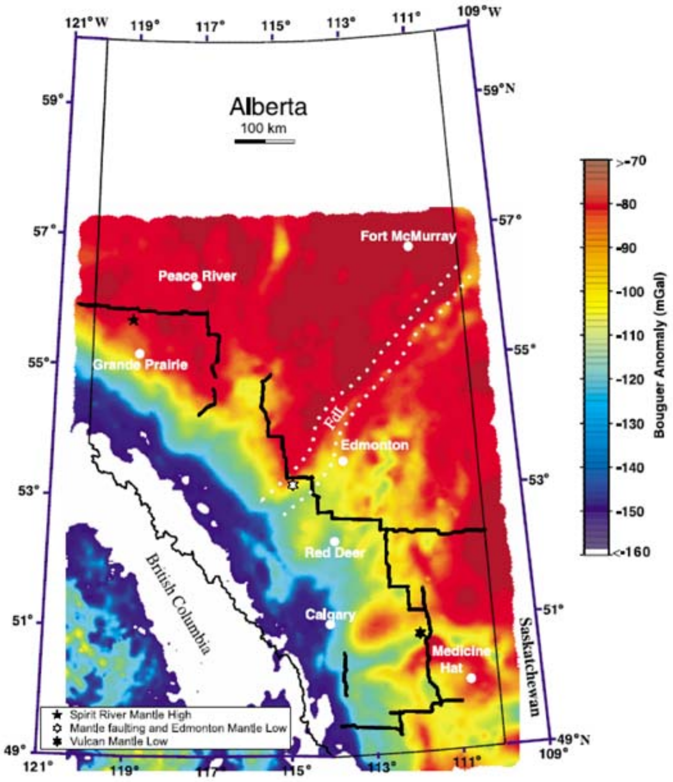


Combined with other seismic and petrologic data, many researchers believe they represent a zone of partial melt, overlain by aqueous fluids. Additional evidence for widespread melting comes from magnetotelluric data that show that low electrical resistivity is coincident with the seismic reflections (*Unsworth et al.*, 2005).

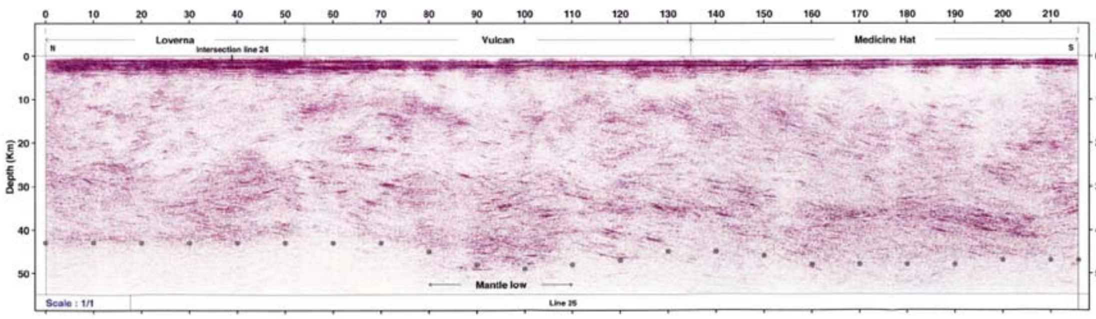


2.10.4 LITHOPROBE

Lithoprobe was a federally funded geoscience project that used combined geology and geophysics to study the structure and tectonic evolution of a number of regions of Canada between 1980 and 2000. Deep seismic reflection was an integral part of several transects. This included marine seismic data collection on the west coast and in the Great Lakes. Onshore seismic data was collected in other transects, including the Alberta Basement Transect.



The map shows the location of seismic reflection lines in Alberta (black lines). A typical depth section is shown below that extends north-south across the Vulcan structure. The Moho is visible on the right side at a depth of 35-40 km. More details of interpretation are described by *Bouzidi et al.*, (2002).



References

Bouzidi, Y., D. R. Schmitt, R. Burwash, E. Kanasewich, Depth migration of deep seismic reflection profiles: crustal thickness variations in Alberta, *Can. J. Earth Sciences*, **39**, 331-350, 2002.

J. A. Brewer, S. B. Smithson, J. E. Oliver, S. Kaufman and L. D. Brown, The Laramide orogeny: Evidence from COCORP deep crustal seismic profiles in the wind river mountains, Wyoming, *Tectonophysics*, **62**, 165-189,1980.

Brown, L. D., W. Zhao, K. D. Nelson, M. Hauck, D. Alsdorf, A. Ross, M.Cogan, M. Clark, X. Liu, J. Che, Bright spots, structure and magmatism in southern Tibet from INDEPTH seismic reflection profiling, *Science*, **274**, 1688-1690, 1996.

Nelson, K.D., Zhao, W., Brown, L.D., Kuo, J., Che, J., Liu, X., Klemperer, S.L., Makovsky, Y., Meissner, R., Mechie, J., Kind, R., Wenzel, F., Ni, J., Nablek, J., Leshou, C., Tan, H., Wei, W., Jones, A.G., Booker, J.R., Unsworth, M., Kidd, W.S.F., Hauck, M., Alsdorf, D., Ross, A., Cogan, M., Wu, C. Sandvol, E., Edwards, M., Partially molten Middle Crust Beneath Southern Tibet : Synthesis of Project INDEPTH results, *Science*, **274**, 1684-1686, 1996.

Unsworth, M.J. A.G. Jones, W. Wei, G Marquis, S. Gokarn, J. Spratt, Crustal rheology of the Himalaya and Southern Tibet inferred from magnetotelluric data, *Nature*, **438**, 78-81, doi:10.1038/nature04154, 2005.