Correlation between crustal high conductivity zones and seismic activity and the role of carbon during shear

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INTRODUCTION

It has been recognised for some years that certain sections of the Earth's crust have anomalously high electrical conductivities. Many physical mechanisms have been proposed to explain this, all of which rely on a single highly interconnected conductive phase. The difficulty is knowing which conducting phase or phases are responsible at any given location.

Aqueous fluids are often cited as a possible conducting phase. Aqueous fluids can explain many regions of anomalously high electrical conductivities in the upper crust, but run into geochemical difficulties in the anhydrous granulite of the lower crust. Graphite has also been proposed, and although it was initially uncertain whether sufficient graphite could be deposited in a sufficiently connected fashion to give rise the required conductivities, recent work has shown this to be so. Highly conducting films of graphite can be deposited in rocks during fracturing in the presence of a CO/CO_2 fluid, but more recently nearly perfect crystallized graphite has been formed by pressure and temperature treatment representing crustal conditions leading to increases in conductivity by approximately three orders of magnitude. The hypothesis that graphite is found on shear planes and is associated with shear movement is also supported by Bustin *et al.* who showed that graphite formation is aided significantly by shear strain and strain energy.

Partial melting can also be the cause of high conductivities. However, partial melting is only likely to be present in areas of recent tectonism where the local geotherm is high. Solid state conduction through the rock forming minerals themselves has often been thought to be insufficient to explain the observed conductivities even in rocks with hydrous mineralogies. Other possible conducting phases are accessory minerals such as magnetite and sulphides, but these are almost always present in distributions which have much too low connectivity to give an overall high rock conductivity.

The explanation of raised conductivities within the crust is likely to arise from a number of these proposed mechanisms, and some are likely to be more dominant at any given location. It is also possible that some of the proposed mechanisms will give rise to changes in other geophysically measured properties, such as seismic attenuation and seismicity. The first part of this poster examines a large, highly conducting zone in north-west Hungary, and relates it to the high seismic attenuations and the seismicity of the area. The second part of the poster shows that shearing of carbon-containing rocks can result in higher electrical conductivities which increases the electrical connectivity of the carbon and we interpret to arise from smearing of the carbon. This mechanism also reduces the strength of the rock, which we believe explains the observed high seismic attenuations and the seismicity of north-west Hungary.

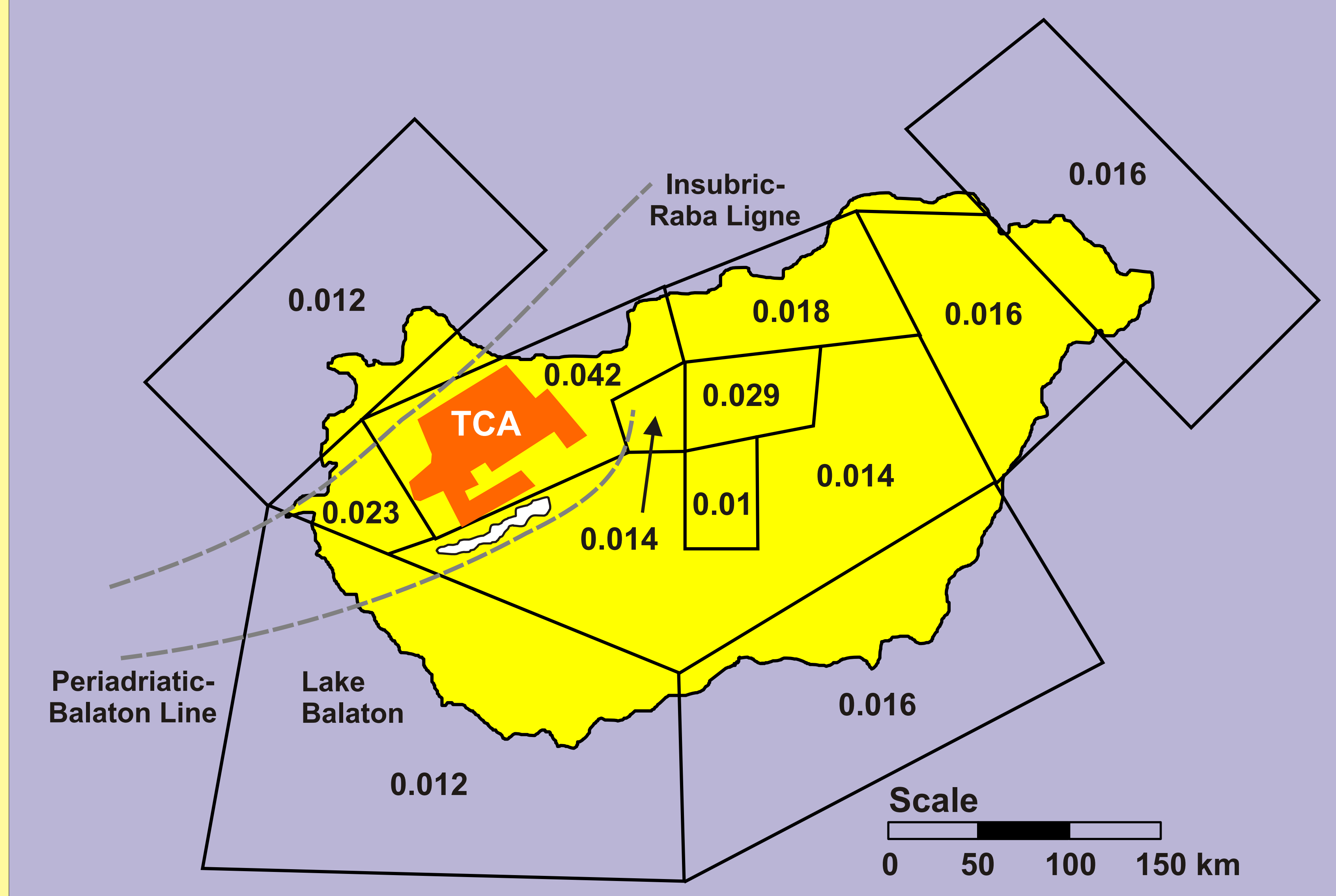
TRANSDANUBIAN CONDUCTIVITY ANOMALY

A large, highly conducting, crustal zone has been detected in north-west Transdanubia, Hungary (Transdanubian Conductivity Anomaly, TCA) by telluric and magneto-telluric (MT) observations.

This zone lies between the Periadriatic-Balaton and Insubric-Raba tectonic lines. The formations between these tectonic lines represent material that was expelled eastwards into the Pannonian Basin as a result of alpine orogeny.

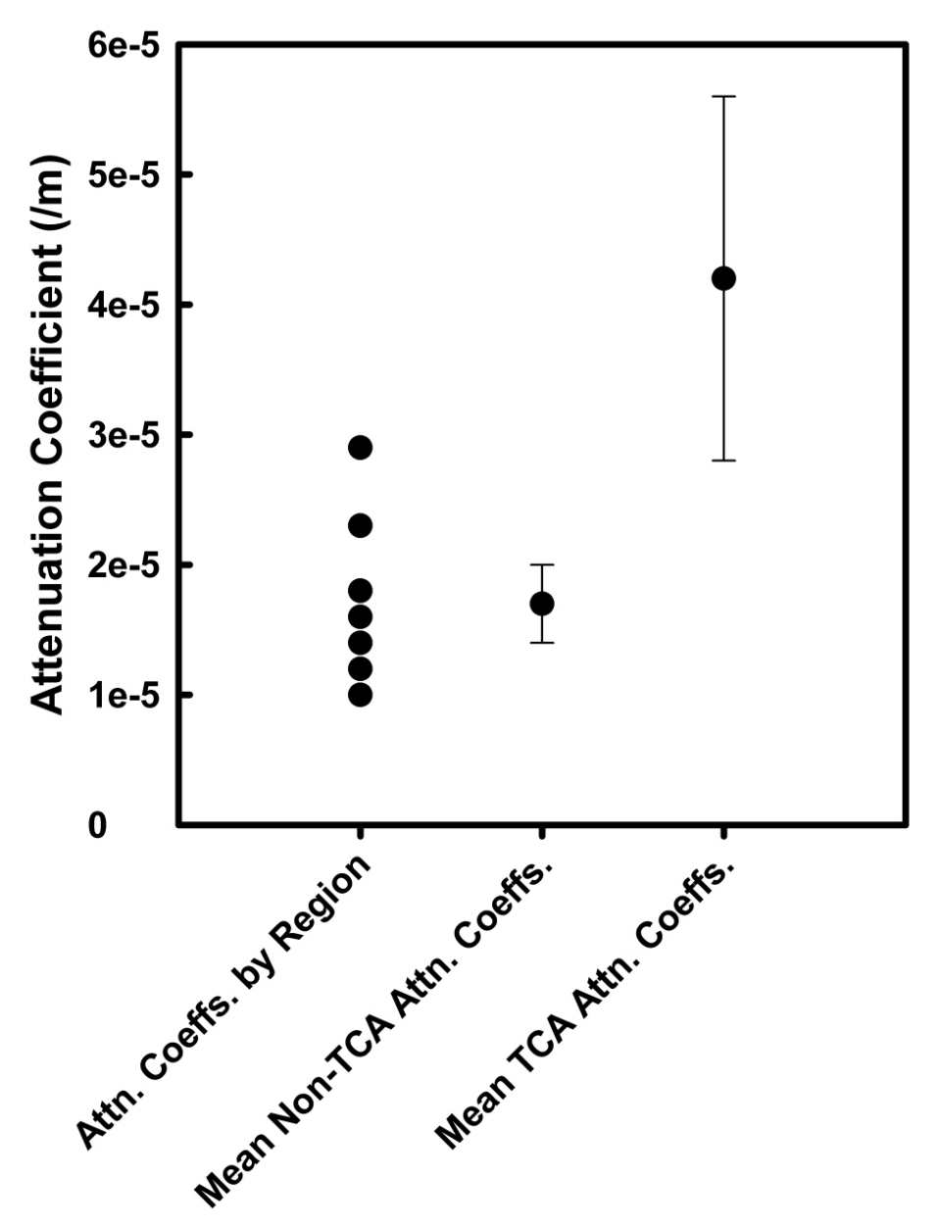
The high conductivity zone consists of several wide stripes at 3-12 km depth. Recent analysis of high resolution MT data from the area shows regions of high conductivity at depth that are consistent with sub-vertical fracture zones striking 060±008° (i.e., parallel to the strike of the known longitudinal fractures/strike-slip fractures of the Pannonian Basin). The conductance of the zones is high, reaching 2×10^4 S, with a high degree of lateral electrical anisotropy (approximately 1000 to 1). The highest conductivities coincide with the direction of the *in situ* fractures, and the lowest conductivities are in the direction perpendicular to the fracture surfaces. Tracing the anomaly to the west using MT measurements reveals it to be related strongly to graphitic schists and black shales cropping out in the Gail Valley Alps. It is here that the Insubric-Raba and the Periadriatic-Balaton tectonic lines converge to a narrow channel from which the Transdanubian central range and the region occupied by the TCA were squeezed out. At present, however, there are no deep boreholes in Transdanubia capable of confirming that graphite or carbon-bearing rocks exist at depth.

MEASUREMENT LOCATION



Values are sesimic attenuation coefficients.

SEISMIC ATTENUATION



The seismic attenuation values of each region is less than that of the TCA indicating that the TCA represents highly attenuating rock which is consistent with the region being either:

(i) highly fractured,
(ii) composed partially of graphite, or
(iii) both.

CORRELATION

The figures top right show the correlation between the electrical measurements made on the TCA by the MT technique together with the epicentral depths for earthquakes falling in that area.

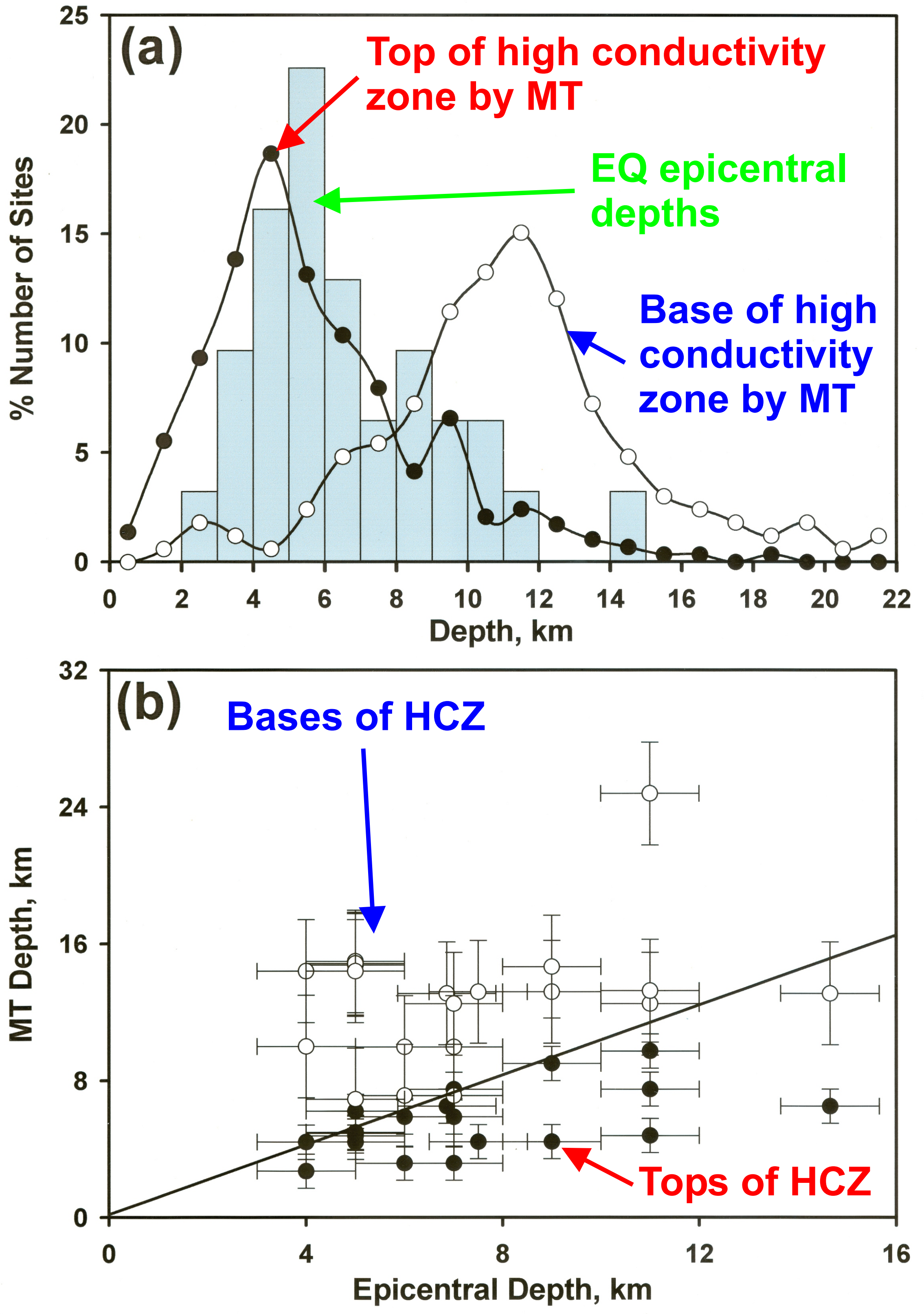
The top figure shows the mean behaviour as a function of depth. It can be seen that the earthquake epicentral depths are almost always falling between the curve for the top and the bottom of the conductive layer as defined by MT measurements.

This is, however, a lumped measurement.

The bottom diagram shows a location by location representation. Here the 1:1 ligne should separate all points representing the top of the conductive zone from those representing the bottom of the zone. Since both vary from locatio to location, this is a better representation of the data.

It also allows us to include the individual uncertainties which also vary from location to location and measurement to measurement.

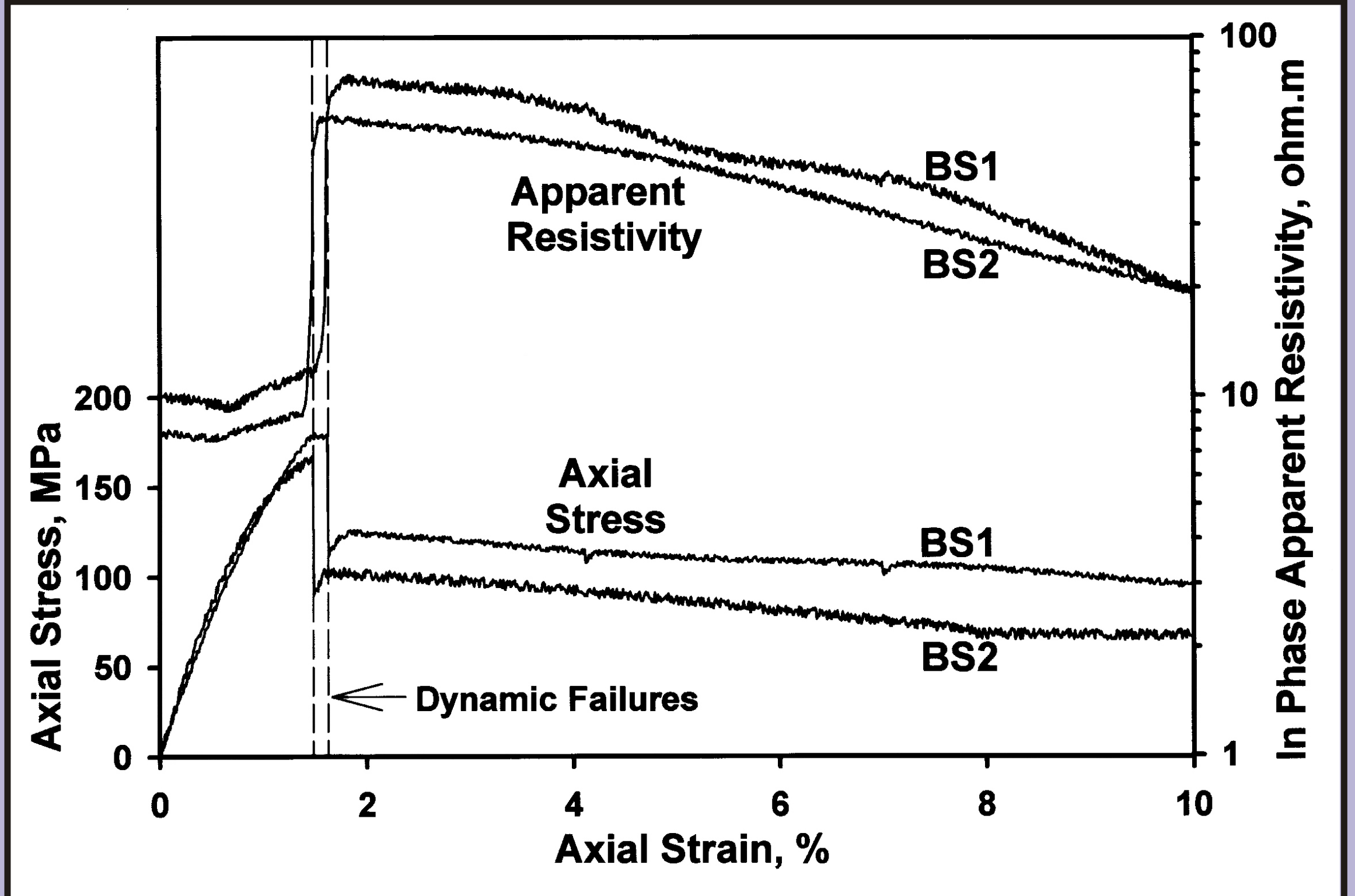
CORRELATION: CONDUCTIVITY & SEISMICITY



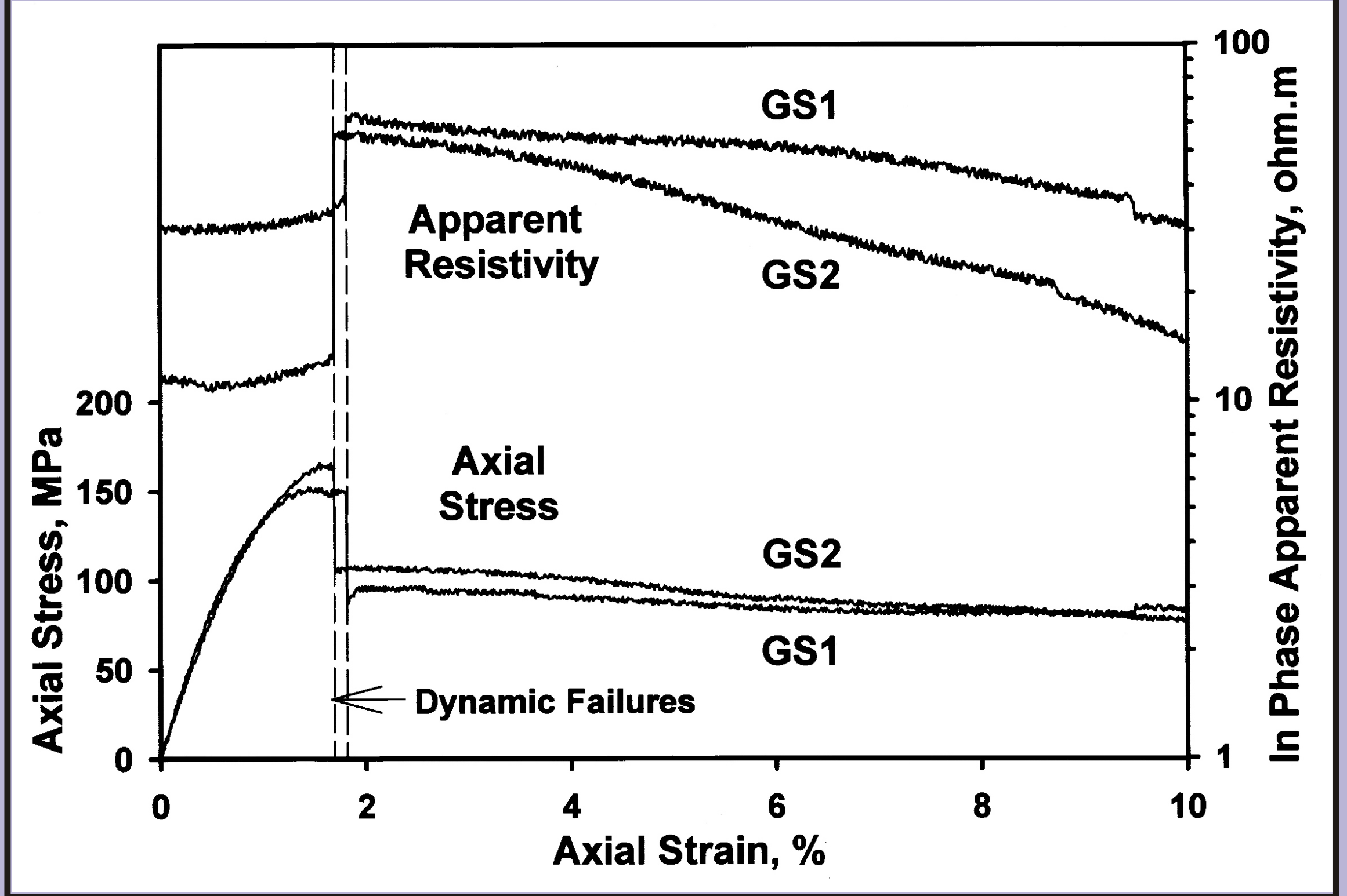
INITIAL ROCK DATA

Sample Code	Carbon Pre-run (%)	Carbon Post-run (%)	Minerals	Porosity (%)	Strain Rate (/s)	Confining Pressure (MPa)
BS1	8.12 ± 0.05	7.95 ± 0.05	56% qtz, 28% alb, 8% pyr, 8% gr	3.24	2×10^{-6}	55
BS2	10.06 ± 0.05	10.86 ± 0.05	57% qtz, 29% alb, 4% pyr, 10% gr	2.67	2×10^{-6}	55
GS1	3.10 ± 0.05	3.02 ± 0.05	35% qtz, 28% plag, 14% musc, 18% bio, 2% gar, 3% gr	1.52	1×10^{-6}	50
GS2	7.37 ± 0.05	7.80 ± 0.05	34% qtz, 27% plag, 12% musc, 18% bio, 2% gar, 7% gr	1.03	1×10^{-6}	50

LABORATORY EXPERIMENTS



Mechanical and electrical measurements on 4 samples of graphite containing rock (Triaxial measurement at 22 degrees C)



SUMMARY

The field data show a clear correlation between the epicentral depths and the extent of the crustal high conductivity zone.

Seismic attenuation measurements show further evidence for deep fracturing that is consistent with the presence of graphite.

The laboratory experiments show clearly that the stress supported by the fracture decreases after failure and the conductivity increases.

We attribute both effects to the smearing of graphite along fracture surfaces.

The graphite, being soft, acts as a lubricant. Further deformation results in more shearing, more smearing and consequently a weaker fracture.

The conductive graphite, when smeared, becomes more connected. The rock then becomes more conductive.

For additional information, please contact:
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