Use of ISC data to improve hypocentral locations: Hindu Kush & Indonesia

Shamita Das

University of Oxford, U.K.

1. We obtain the shape of the seismic zone in the Pamir –Hindu Kush by improving the hypocentral locations of ~6000 shallow and intermediate depth earthquakes.

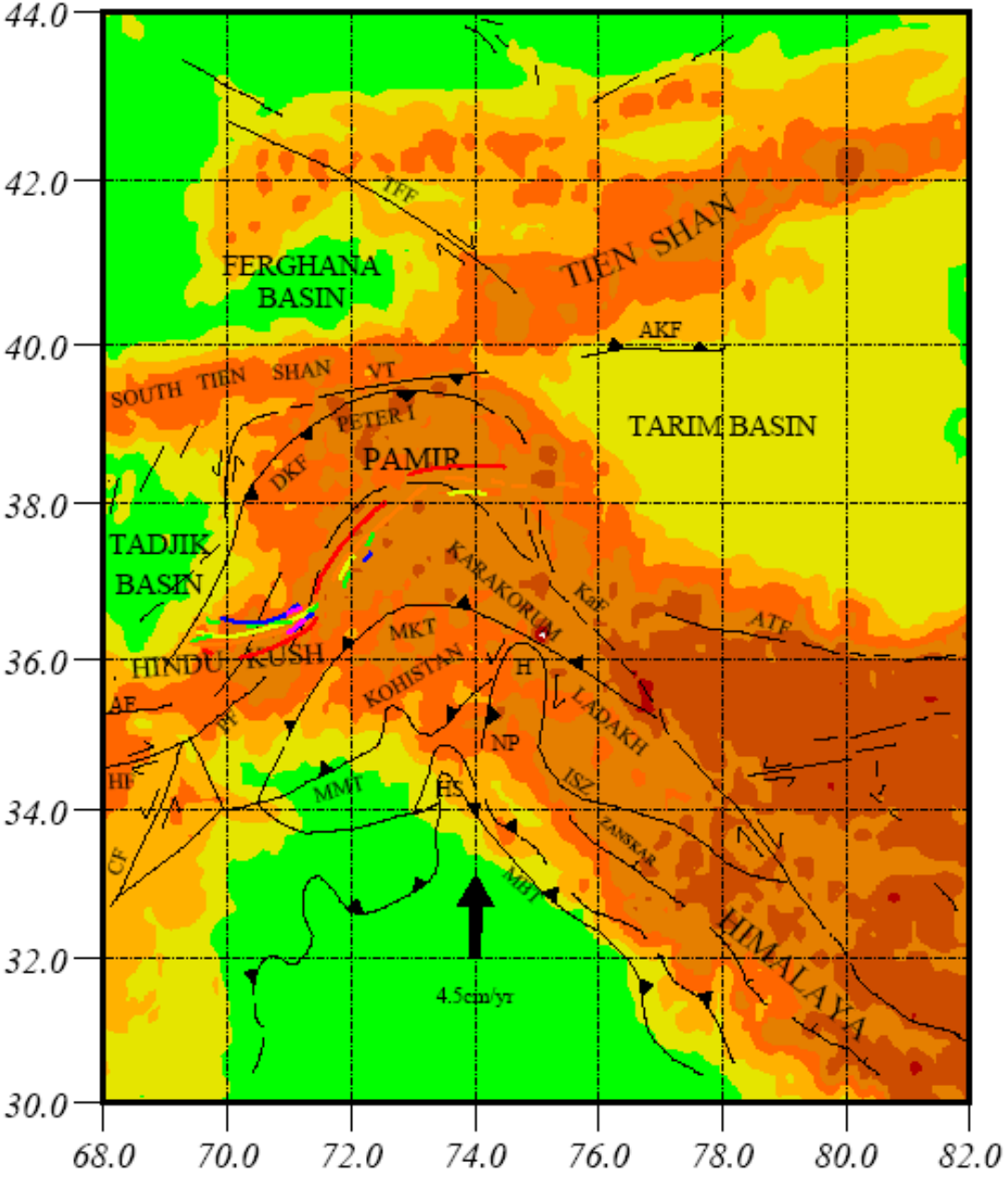
2. P, S and depth phase (when available) arrival time provided by ISC are used in the JHD method

First person to find intermediate depth earthquake under the Pamir- Hindu Kush region was Galitzin in 1911.

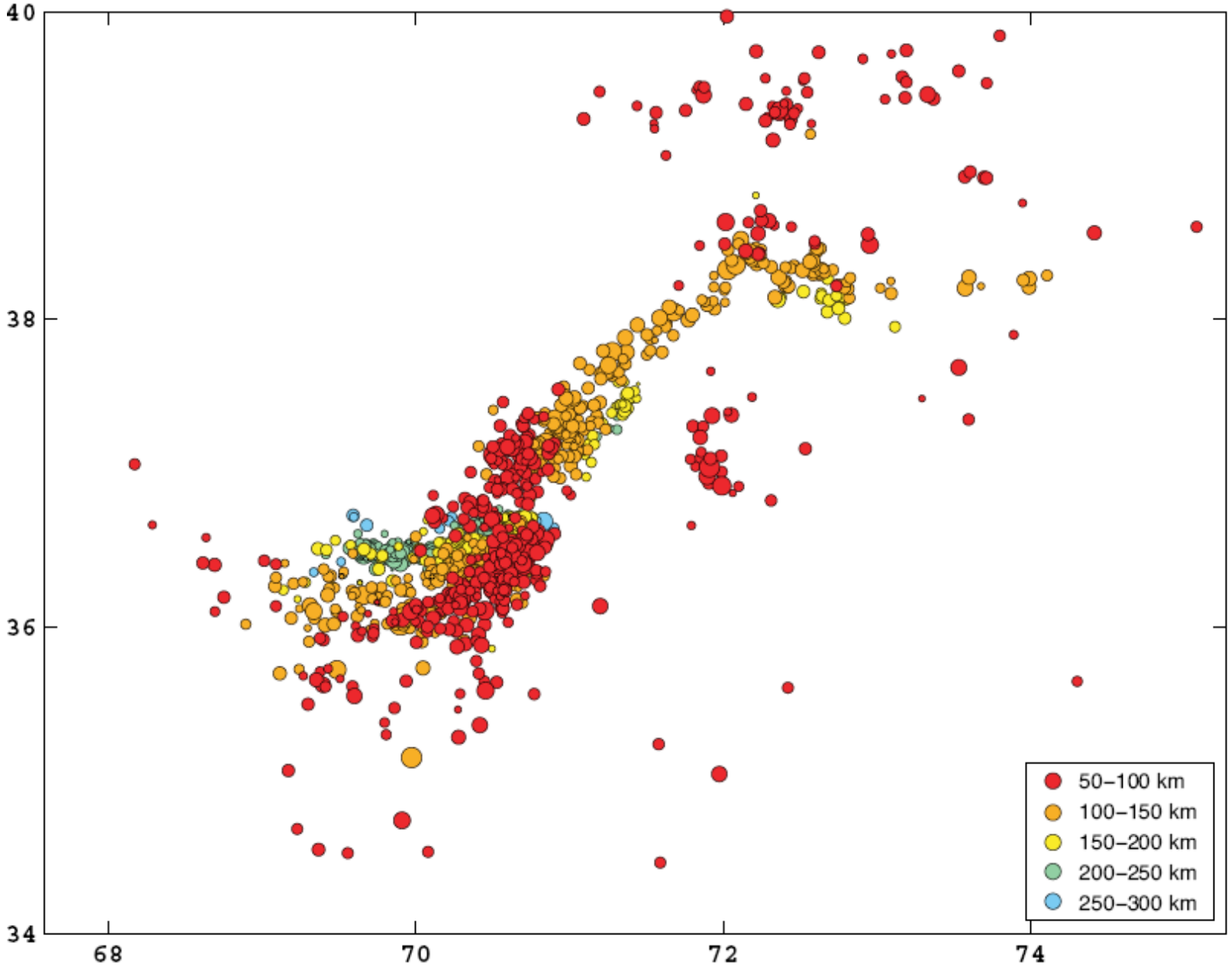
In his ``Elementary Seismology", Richter wrote in 1958 (Chapter 19, Page 311):

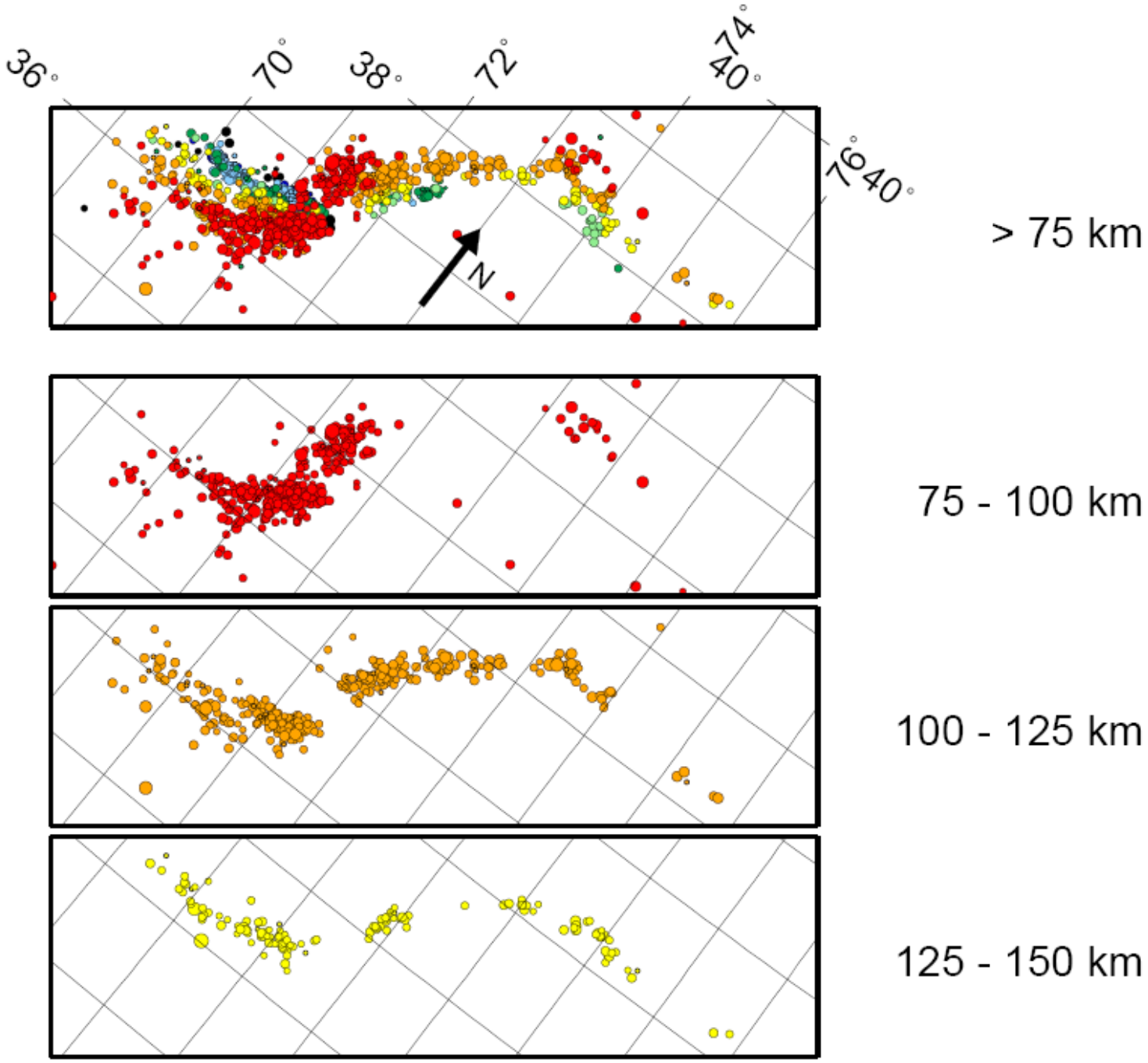
`Depths are often seriously overestimated by taking sP for pP. Sometimes a majority of stations recording a given earthquake report a large sP and overlook or fail to find a pP. This is common with inter-mediate shocks under the Hindu Kush.'

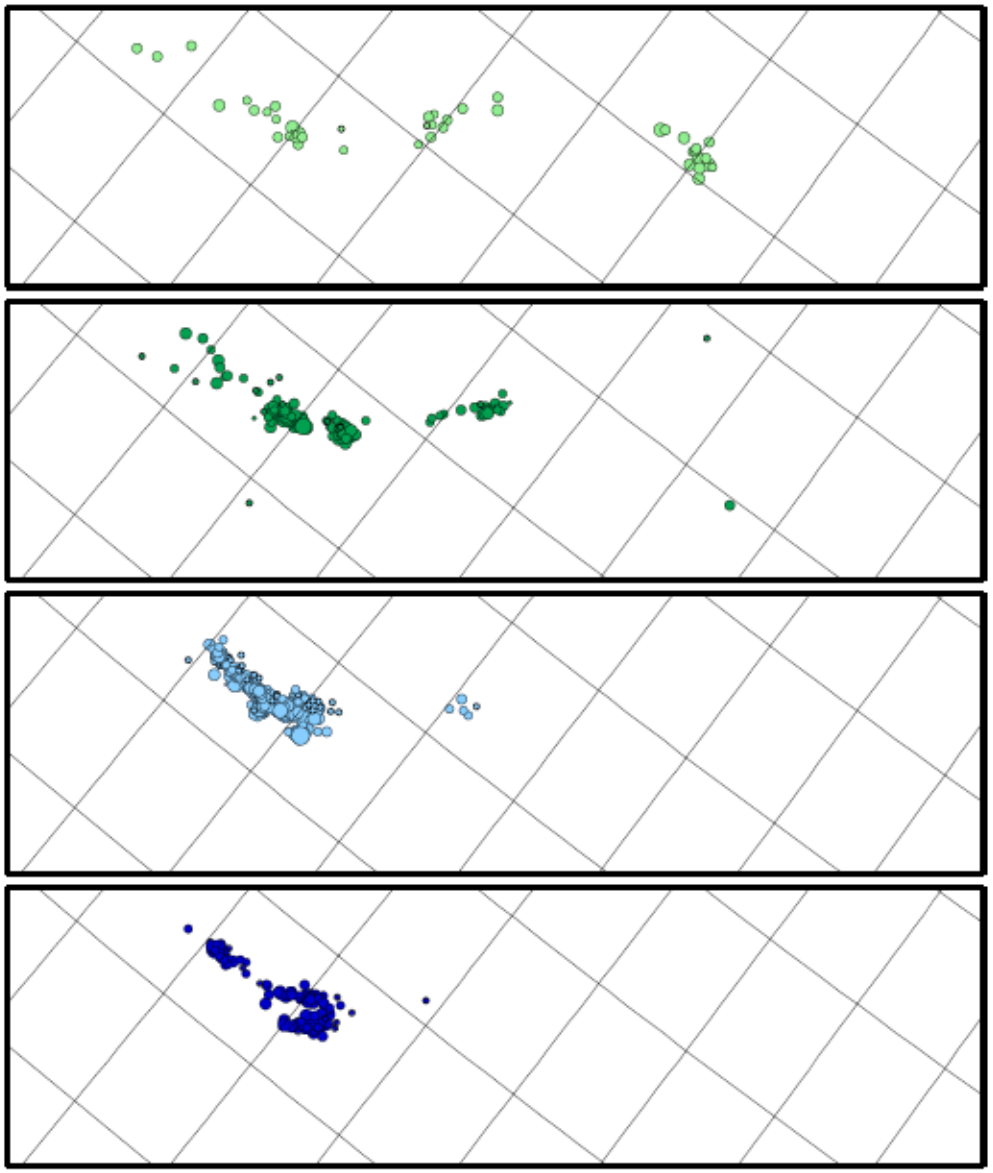
To obtain the best possible hypocentral locations, the study region is divided into 3 depth ranges, 0-60 km, 60-160 km and >160 km. The 0-60 km depth zone is then sub-divided laterally into 19 blocks, with the deeper regions divided into 2 blocks each.

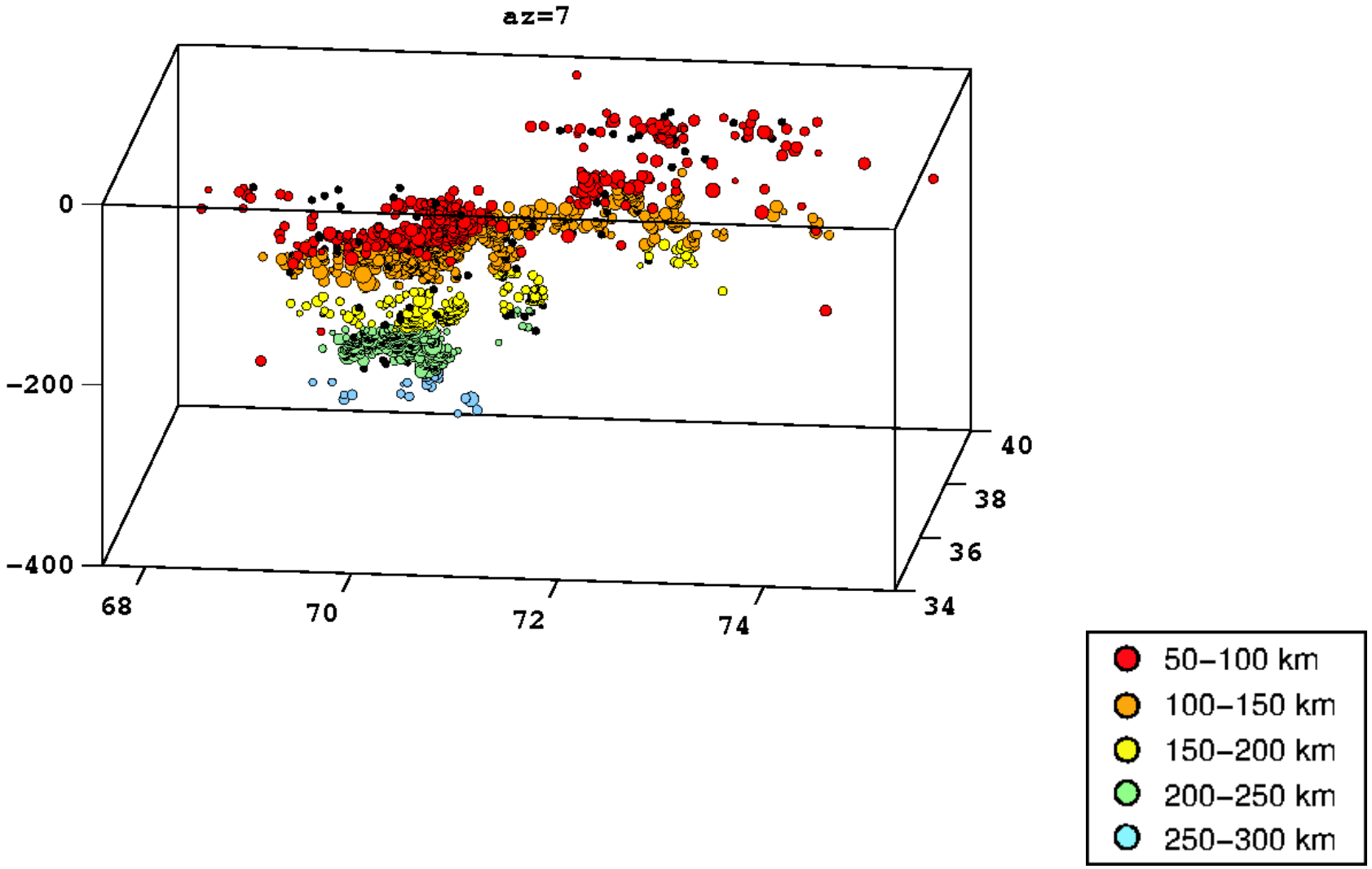

44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
68.0
70.0
72.0
74.0
76.0
78.0
80.0
82.0
TFF
FERGHANA
BASIN
TIEN SHAN
AKF
SOUTH TIEN SHAN
VT
PETER I
DKF
PAMIR
TARIM BASIN
TADJIK
BASIN
KARAKORUM
KKF
ATF
MKT
HINDU KUSH
KOHISTAN
H
LADAKH
AF
PF
NP
HF
MMT
ISZ
ZANSKAR
CF
MBT
HIMALAYA
4.5cm/yr

Of the 9127 earthquakes given by ISC in the region [30-42°N, 68-78°E] from 1964-1992, ~5900 were successfully relocated, with ~3260 having 90% confidence limits < 30 km.

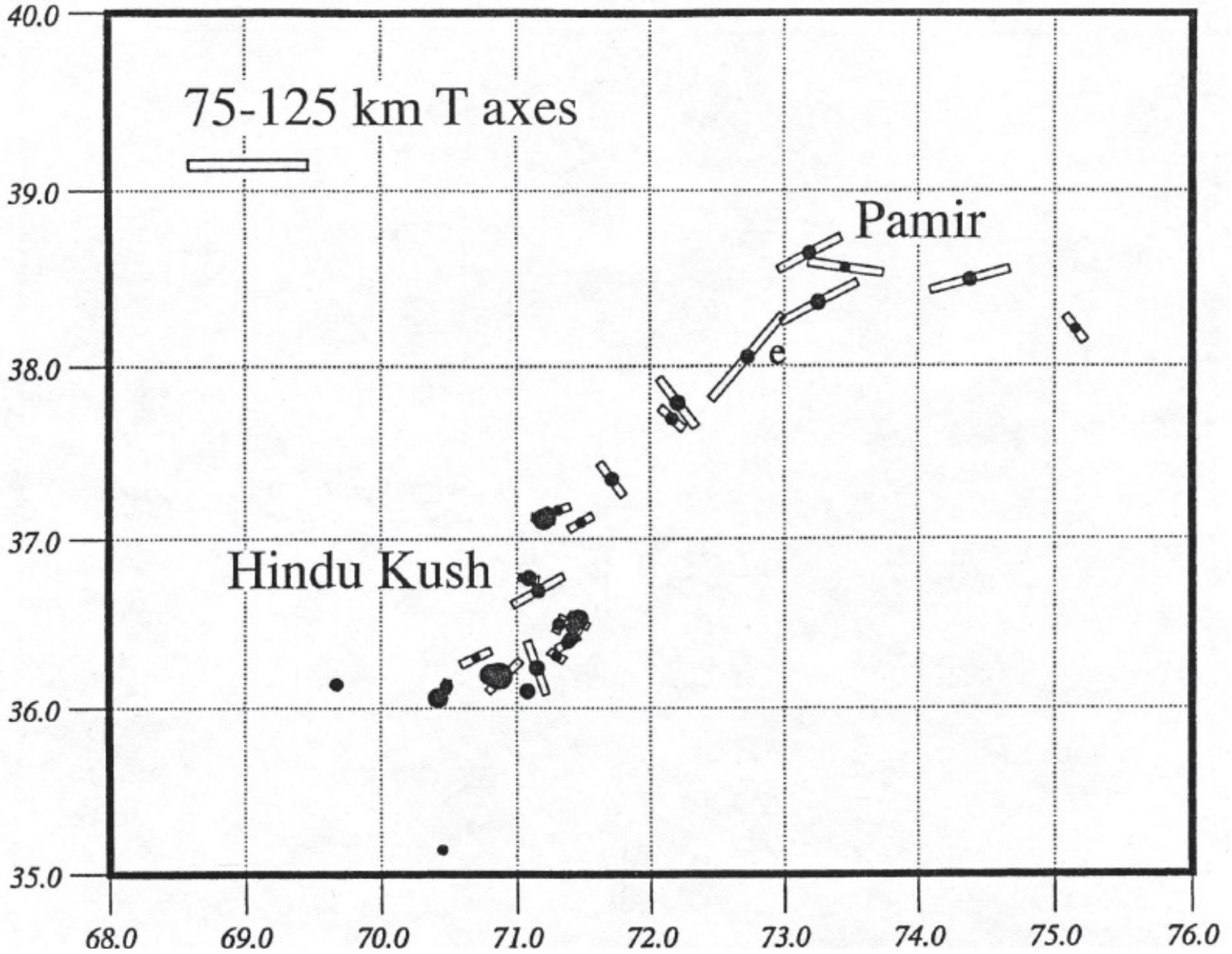

40
38
36
34
68
70
72
74
50–100 km
100–150 km
150–200 km
200–250 km
250–300 km

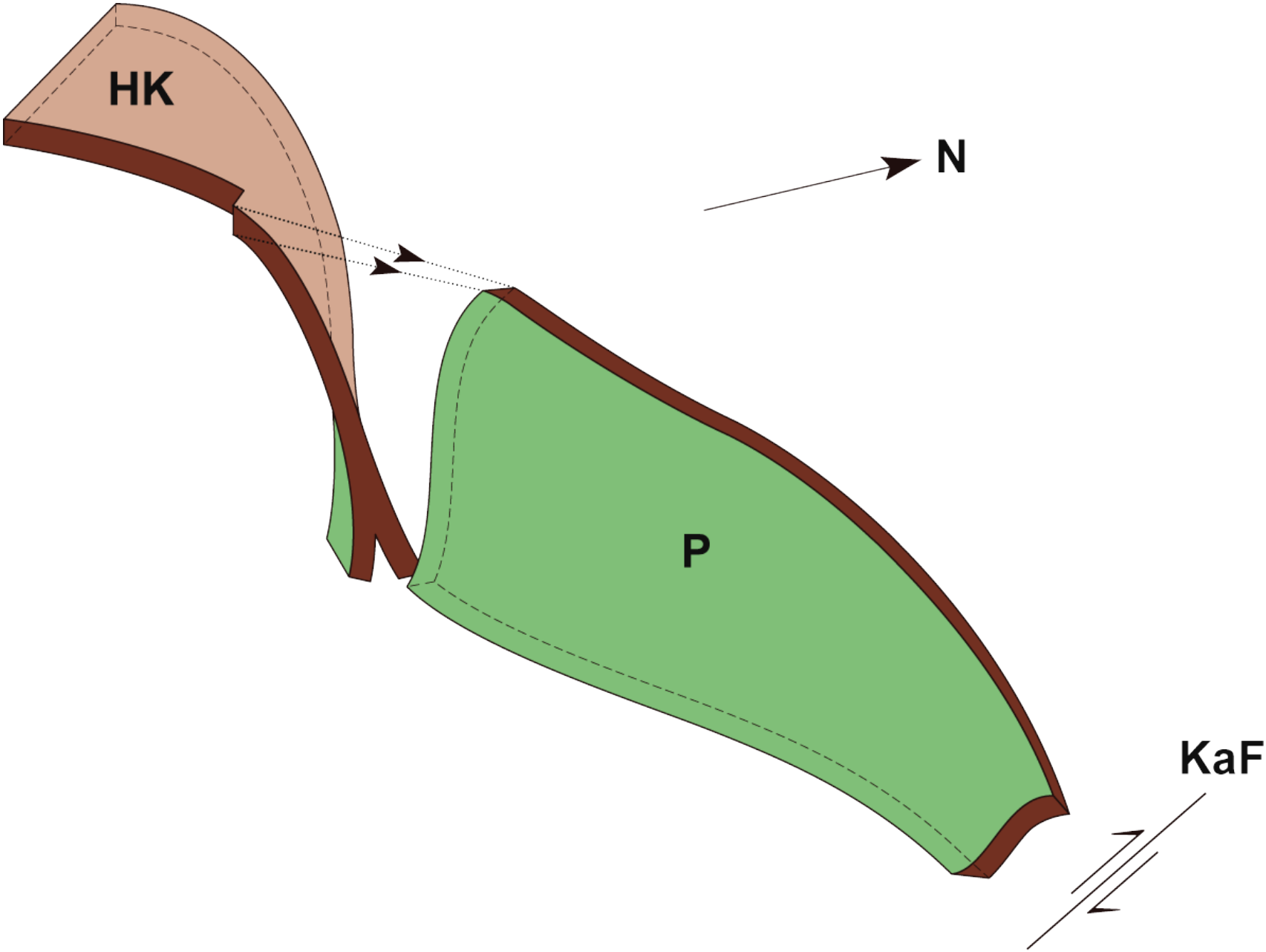

36°
70°
38°
72°
40°
74°
76°
40°
N
> 75 km
75 - 100 km
100 - 125 km
125 - 150 km


150 - 175 km
175 - 200 km
200 - 225 km
225 - 250 km
HK
P


az=7
0
−200
−400
68
70
72
74
34
36
38
40
50–100 km
100–150 km
150–200 km
200–250 km
250–300 km

Open box – Projection of CMT T-axes onto horizontal plane




HK
N
P
KaF

MAIN CONCLUSIONS

1. The improved delineation of the seismic zone obtained using the relocated hypocenters implies that the intermediate depth seismicity in the Pamir Hindu- Kush is most simply explained by a single ``S''- shaped seismic zone, 700 km long and no more than 30 km wide with most activity concentrated at 100-300 km depth.

2. The main features observed are:

(a) The eastward steepening of the north dipping Hindu Kush seismic zone and its overturning at the eastern end under the Pamirs where it dips to the south-east

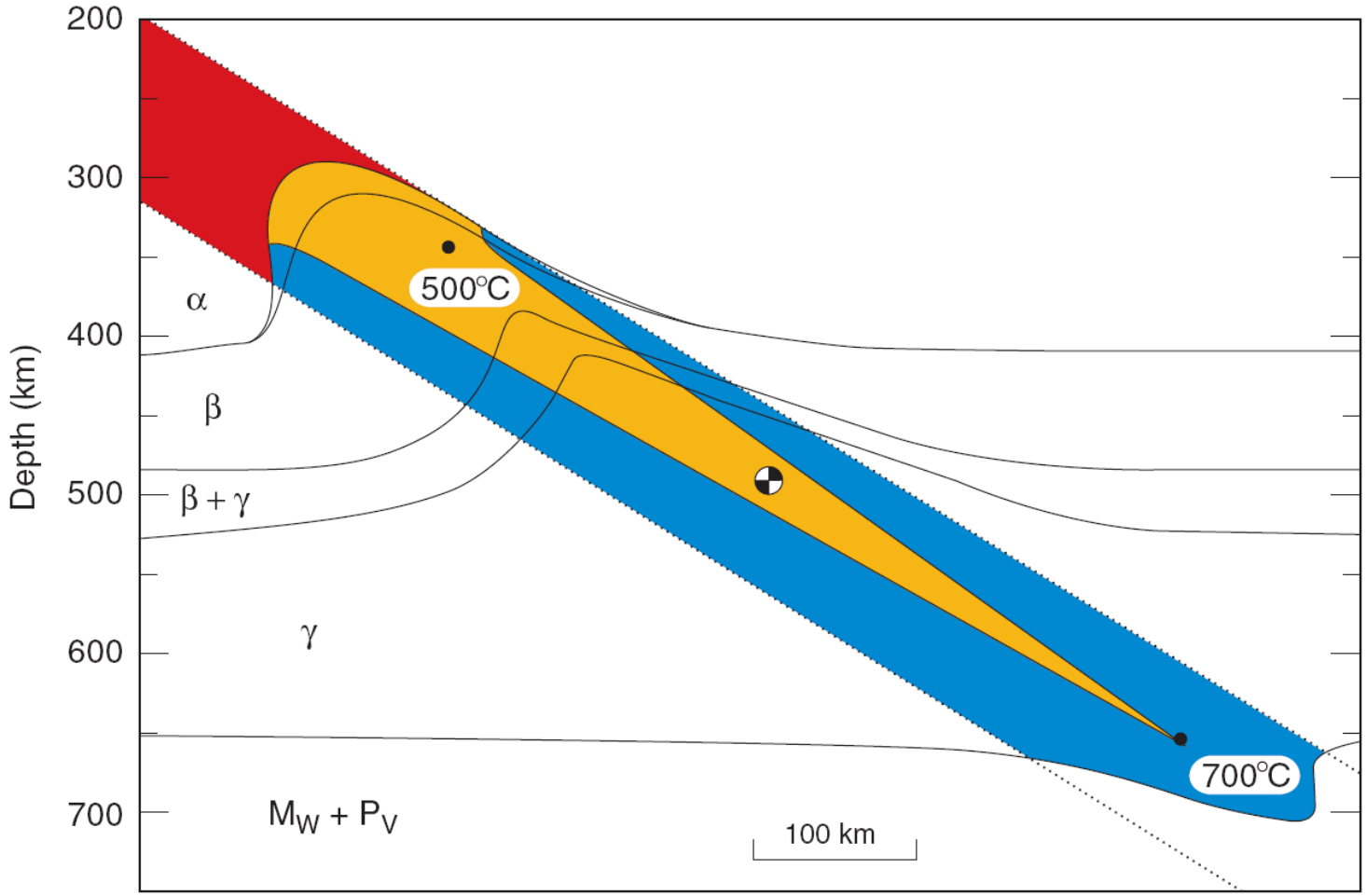
(b) The curvature and tearing apart of the subducted slab at depths > 200 km within the eastern part of the HK seismic zone.

(c) the very abrupt cutoff in intermediate depth seismicity at 90-110 km, with no extension to shallower depths beneath the Pamirs, and with a persistent gap between the intermediate and shallow seismicity in the northern Pamirs

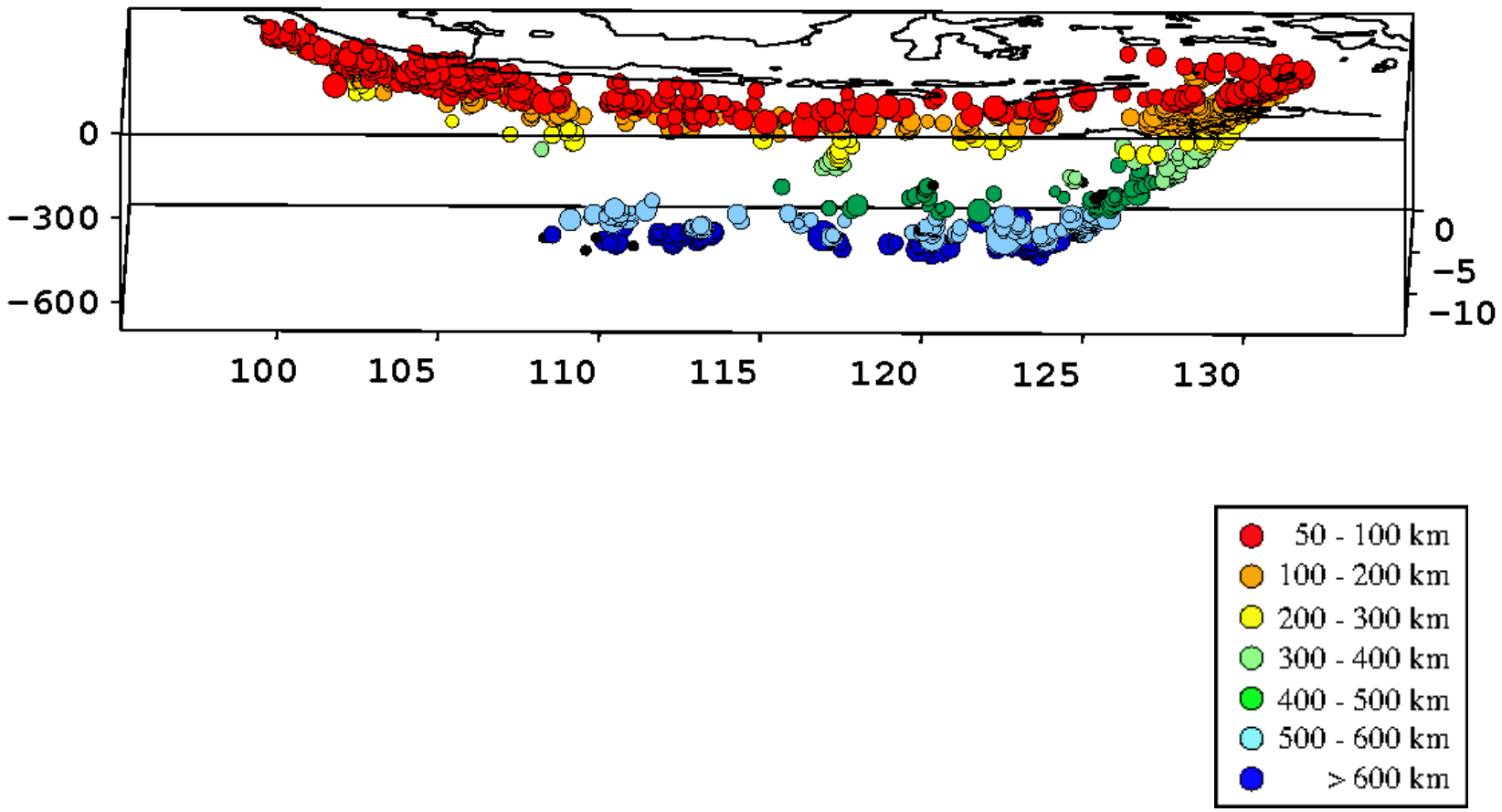
(d) The unusual horizontal T-axes of the intermediate depth earthquakes of the Pamir seismic zone, which aligns with its curvature

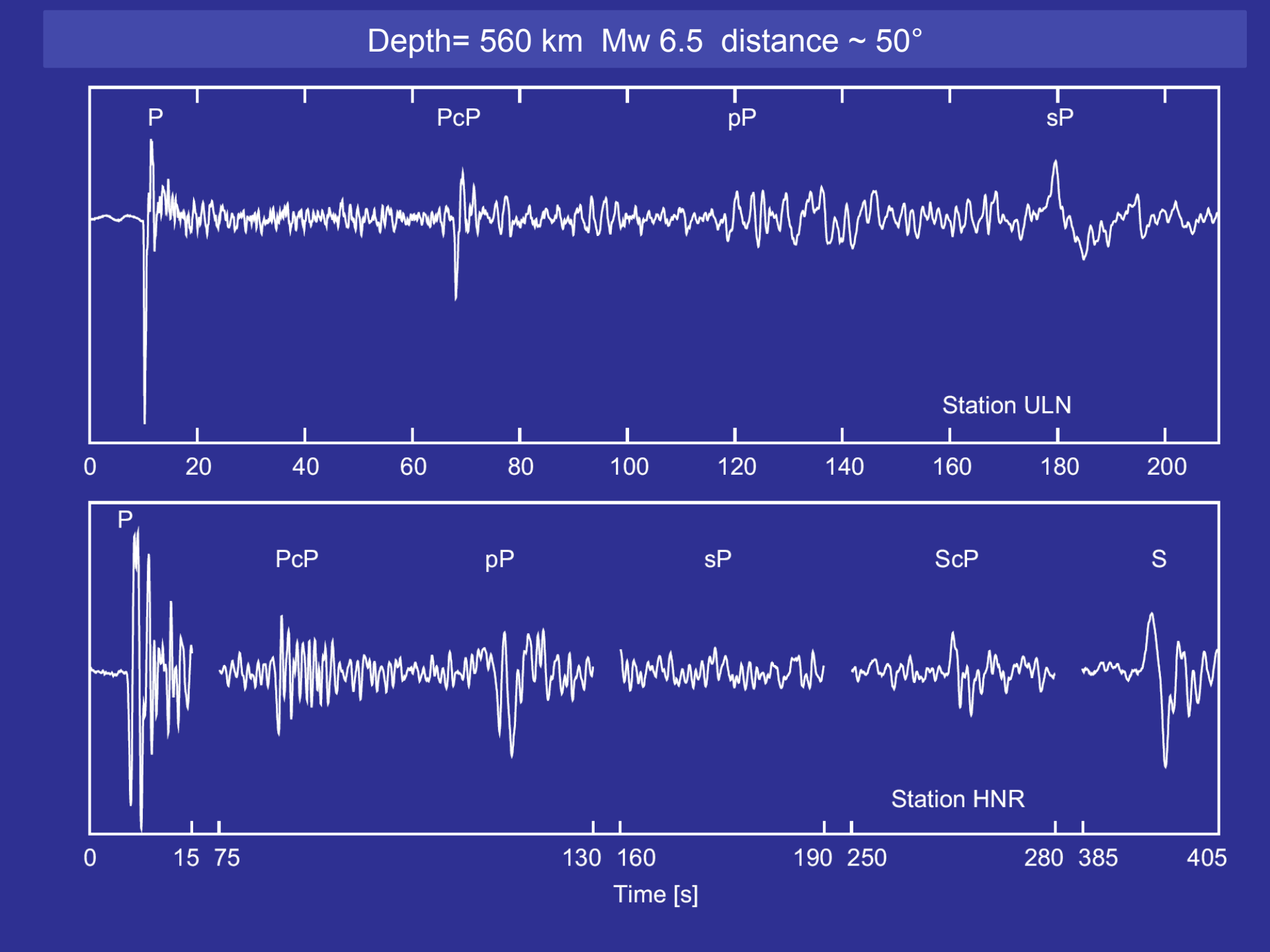
G. Pegler and S. Das (1998) An enhanced image of the Pamir - Hindu Kush seismic zone obtained from relocated earthquake hypocenters, *Geophys. J. Intl.*, **134**, 573-595.

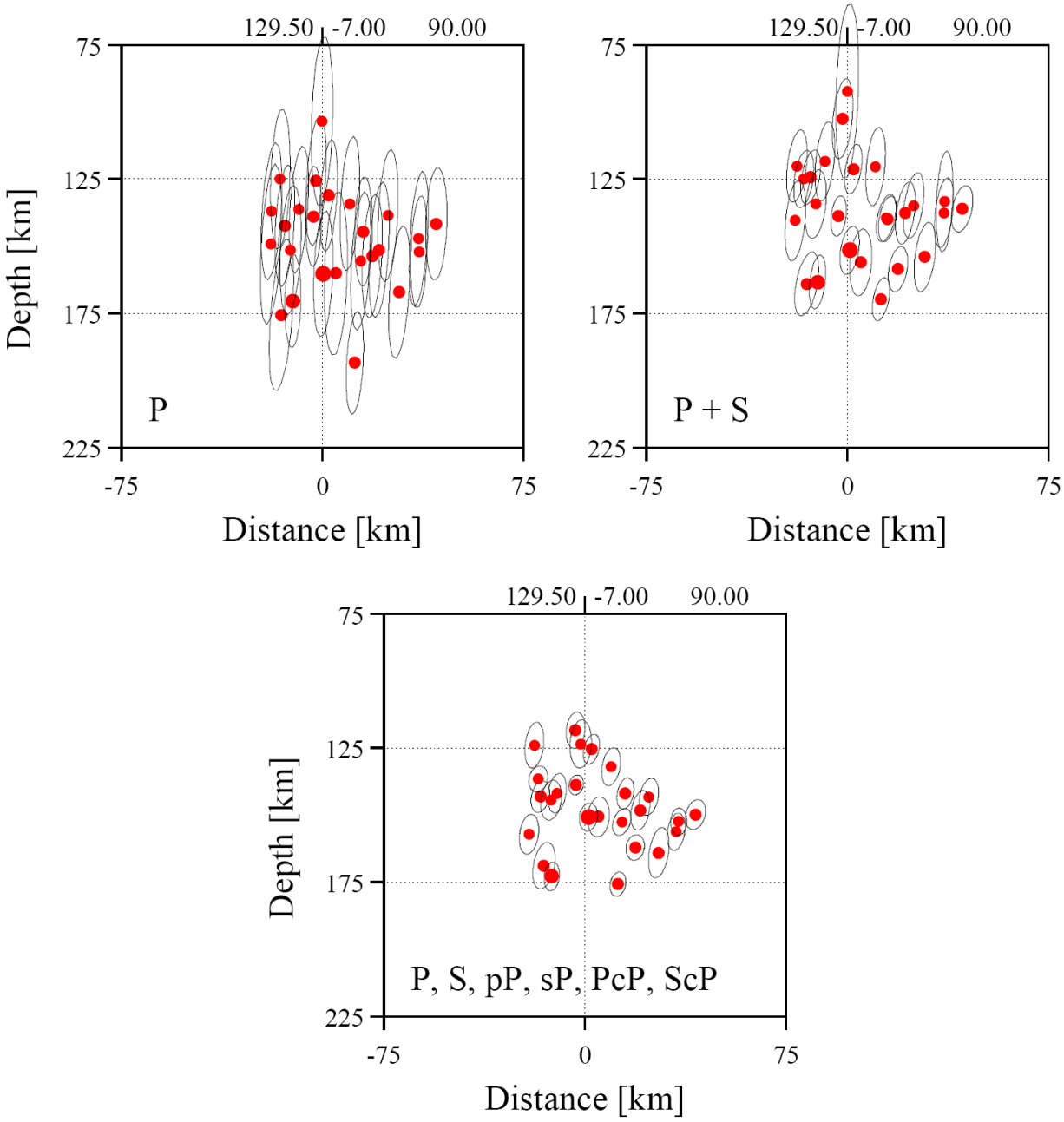
G. L. Pavlis and S. Das (2000) The Pamir-Hindu Kush seismic zone as a strain marker for flow in the upper mantle, *Tectonics*, **19**, 103-115.

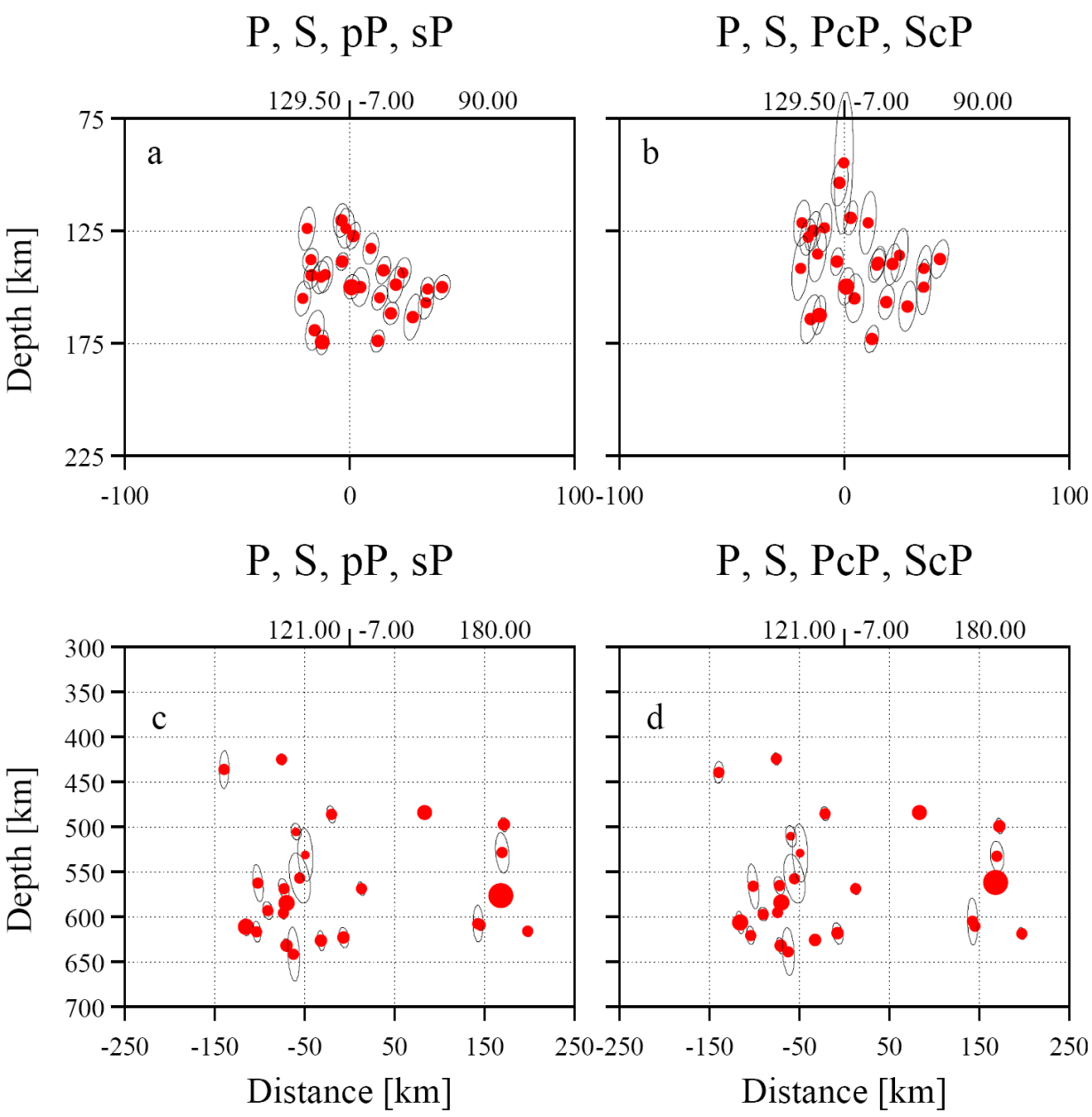

200
300
400
500
600
700
Depth (km)
α
β
β + γ
γ
500°C
700°C
$M_W + P_V$
100 km

Indonesian seismic zone




Depth= 560 km Mw 6.5 distance ~ 50°
P
PcP
pP
sP
Station ULN
0
20
40
60
80
100
120
140
160
180
200
P
PcP
pP
sP
ScP
S
Station HNR
0
15
75
130
160
190
250
280
385
405
Time [s]

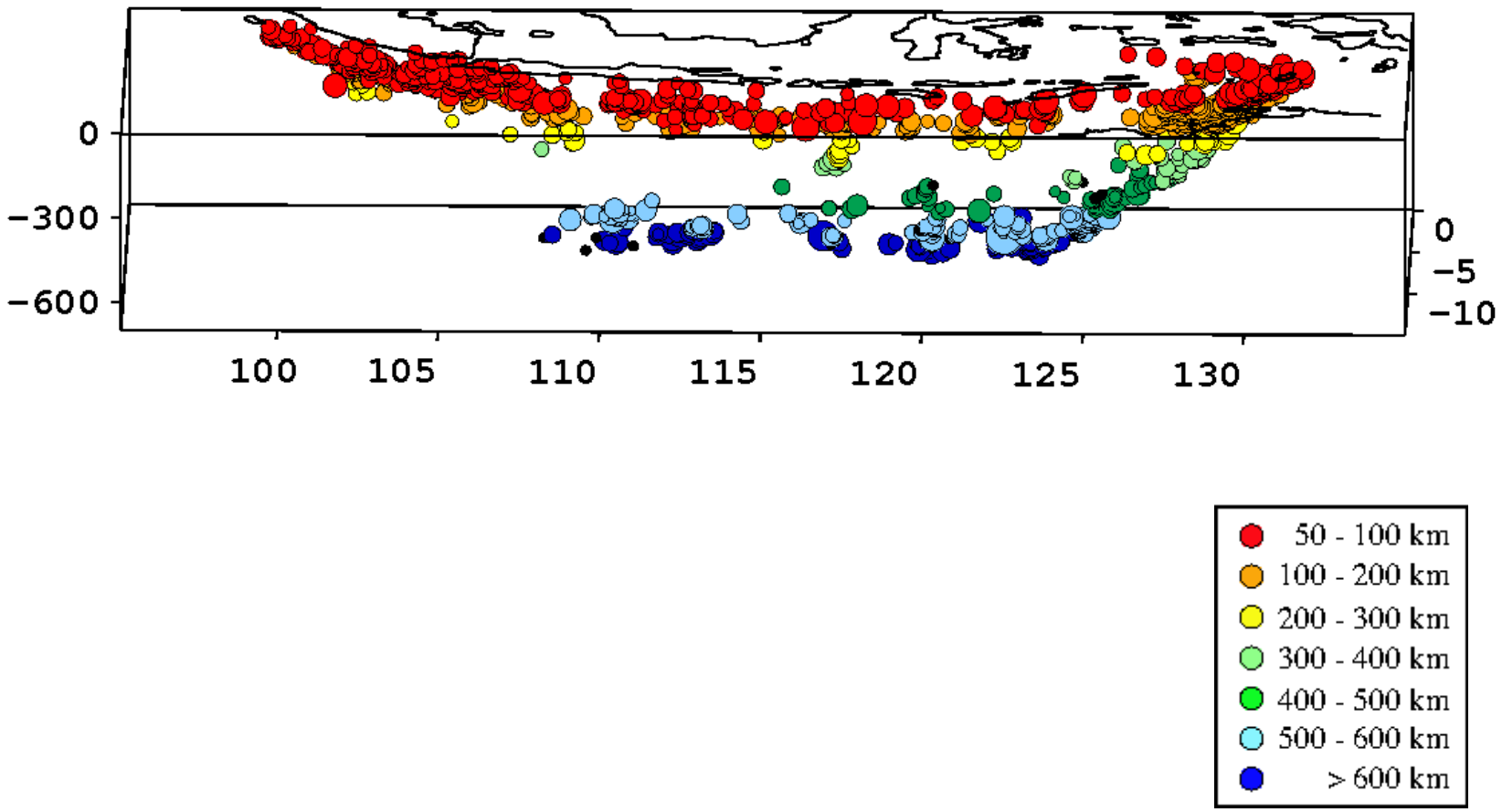

129.50 -7.00 90.00
75
125
175
225
Depth [km]
P
-75
0
75
Distance [km]
129.50 -7.00 90.00
75
125
175
225
P + S
-75
0
75
Distance [km]
129.50 -7.00 90.00
75
125
175
225
Depth [km]
P, S, pP, sP, PcP, ScP
-75
0
75
Distance [km]

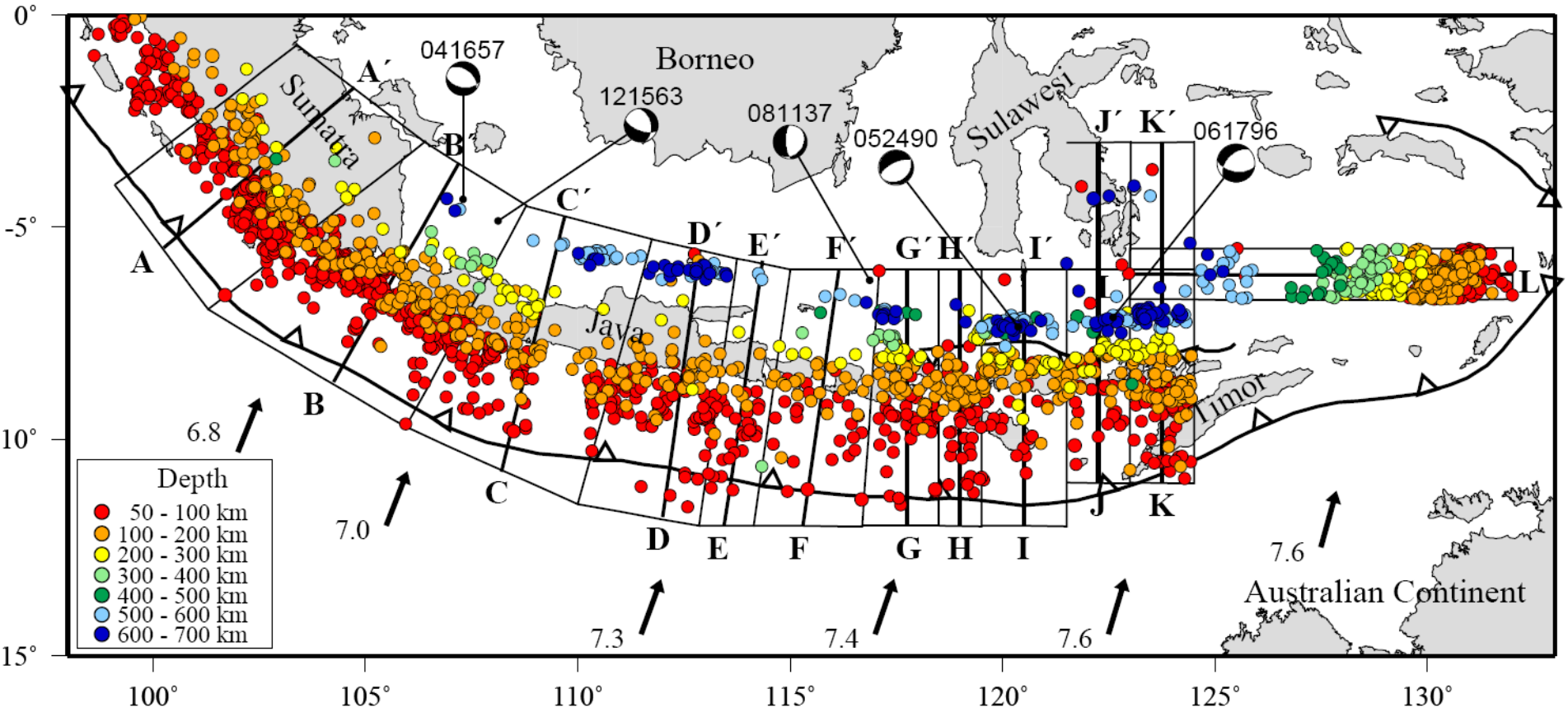

P, S, pP, sP
P, S, PcP, ScP
129.50
-7.00
90.00
a
b
Depth [km]
75
125
175
225
-100
0
100
121.00
180.00
c
d
300
350
400
450
500
550
600
650
700
-250
-150
-50
50
150
250
Distance [km]

Additional phases read for the entire 2600 km Indonesian subduction zone (by examining more than 100K seismograms) :

P	3149
S	1842
pP	1223
sP	920
PcP	1213
ScP	988
Total	9335

Indonesian seismic zone



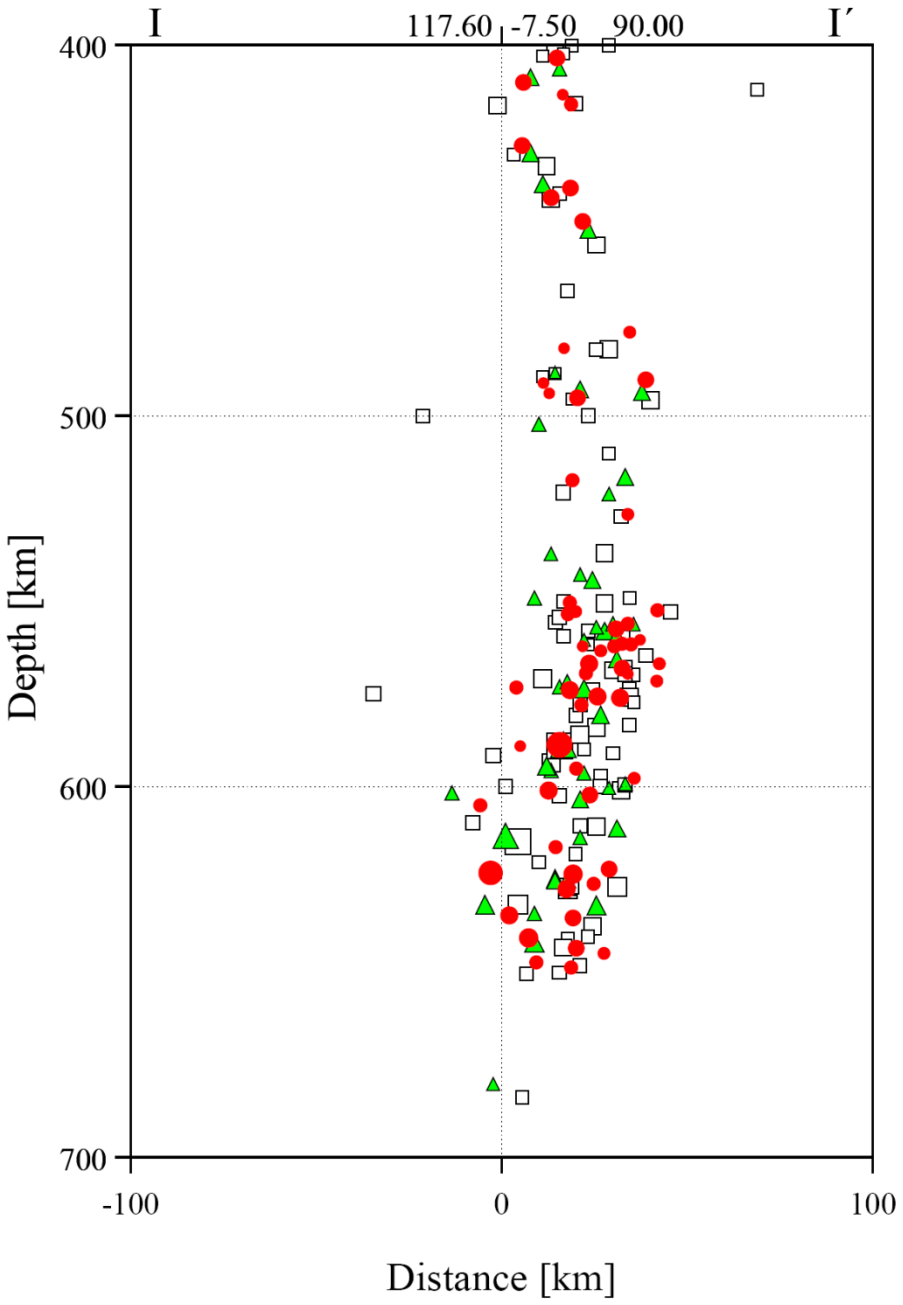

0°
-5°
10°
15°
100°
105°
110°
115°
120°
125°
130°
Borneo
Sumatra
Java
Sulawesi
Timor
Australian Continent
041657
121563
081137
052490
061796
A
A´
B
B´
C
C´
D
D´
E
E´
F
F´
G
G´
H
H´
I
I´
J
J´
K
K´
L
6.8
7.0
7.3
7.4
7.6
7.6
Depth
50 - 100 km
100 - 200 km
200 - 300 km
300 - 400 km
400 - 500 km
500 - 600 km
600 - 700 km

Location comparisons

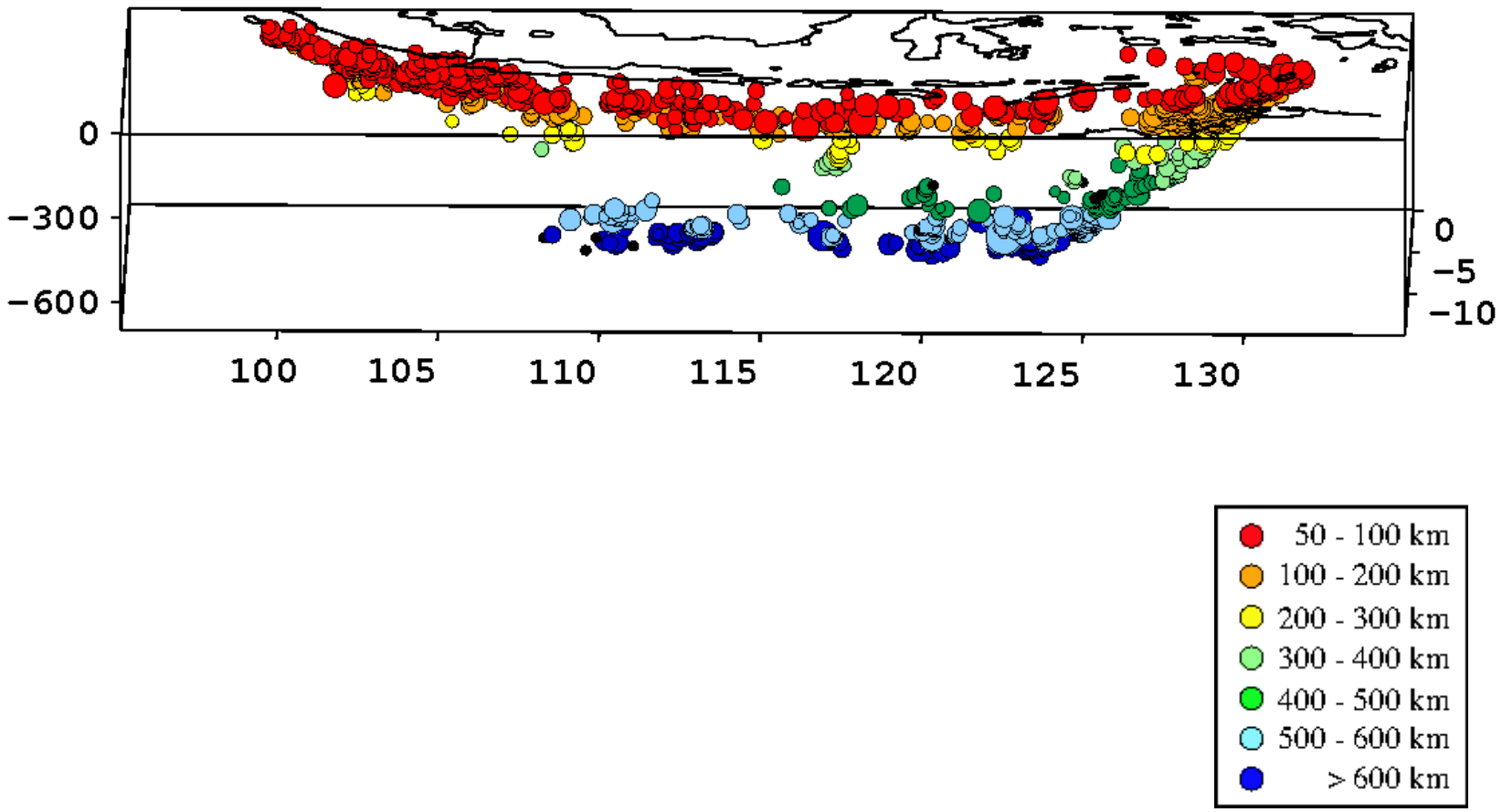
ISC – square (82)

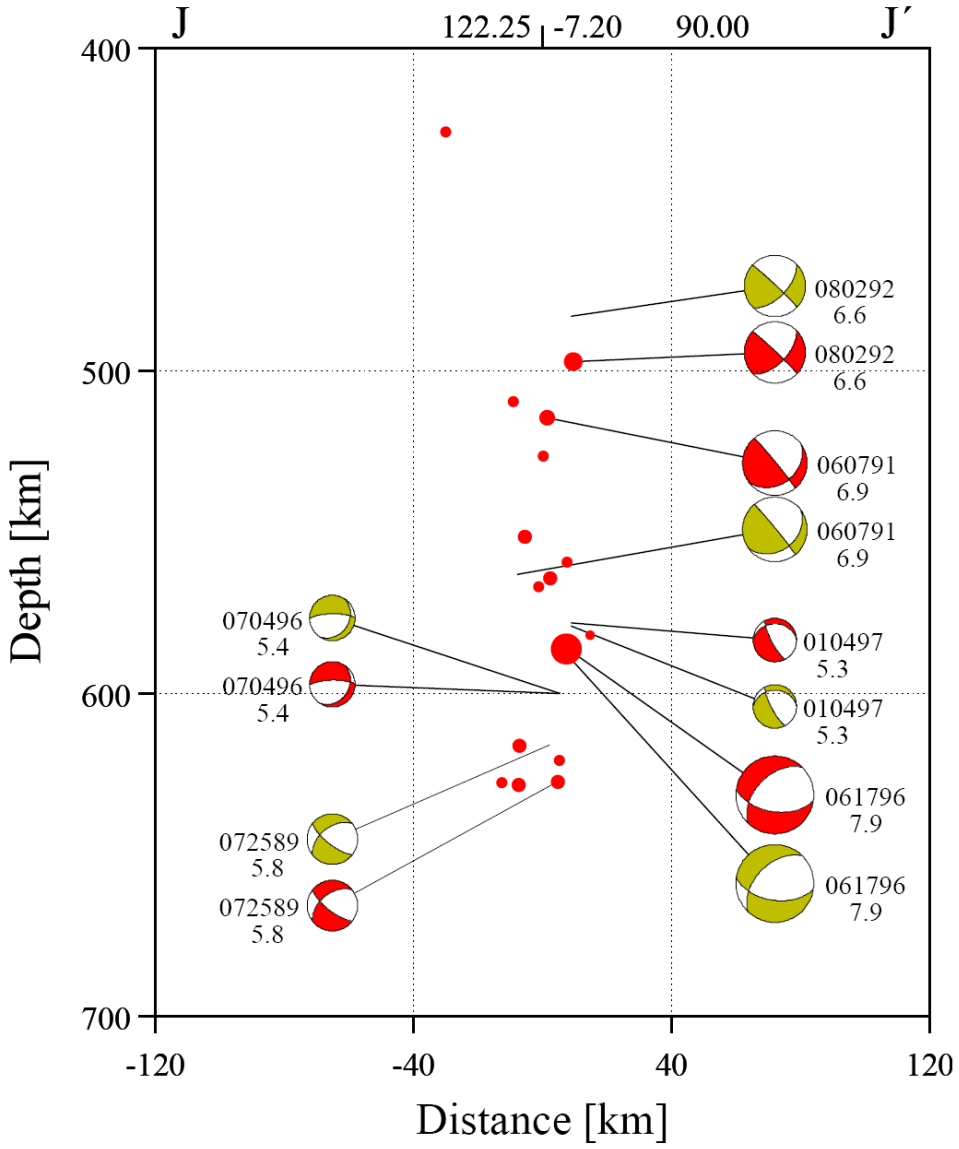
EHB – green
triangle (45)

SD - red dot (59)



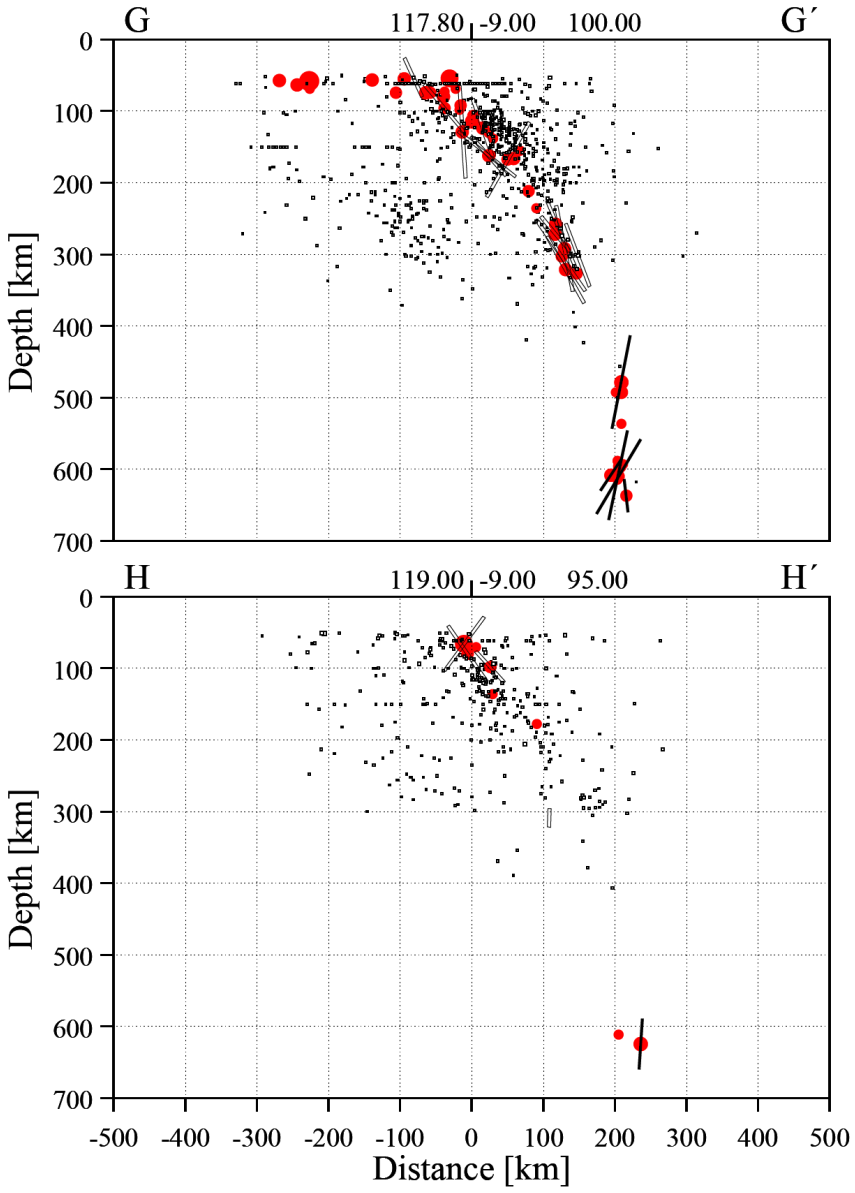
Indonesian seismic zone



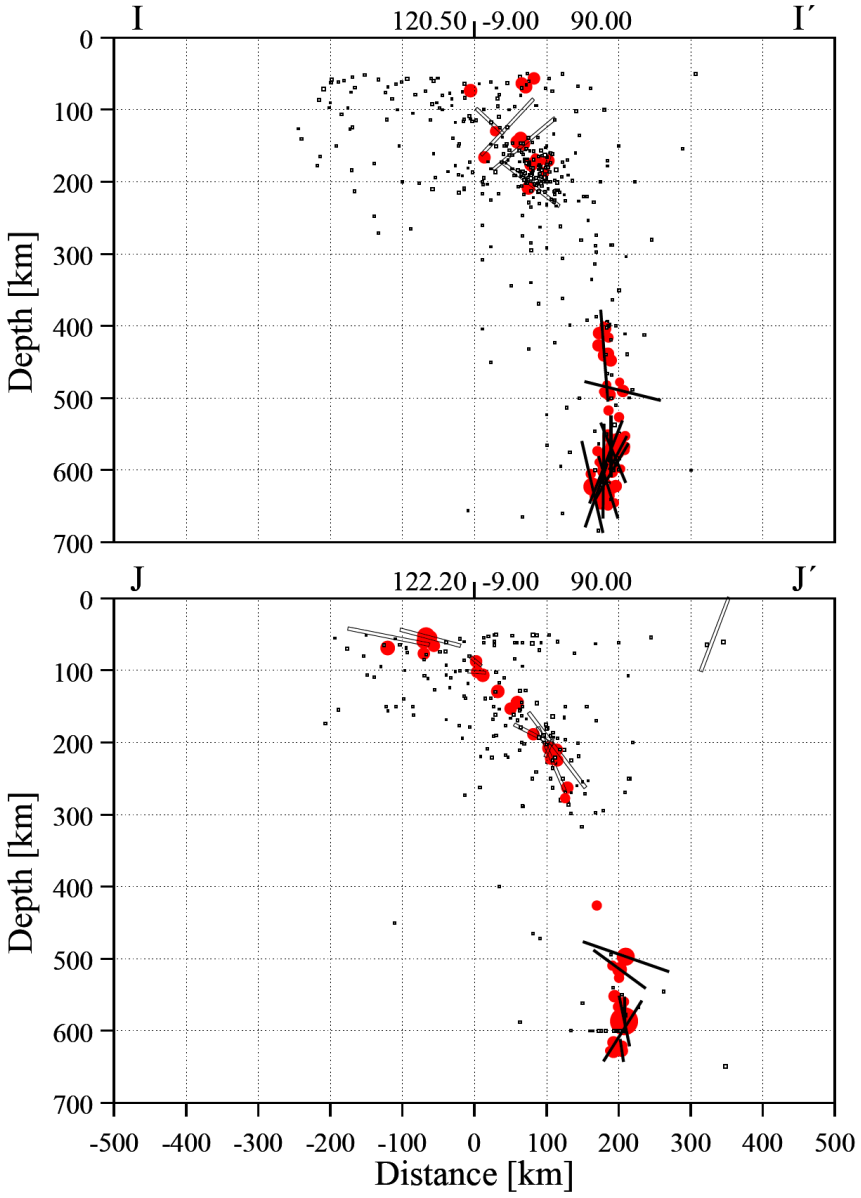


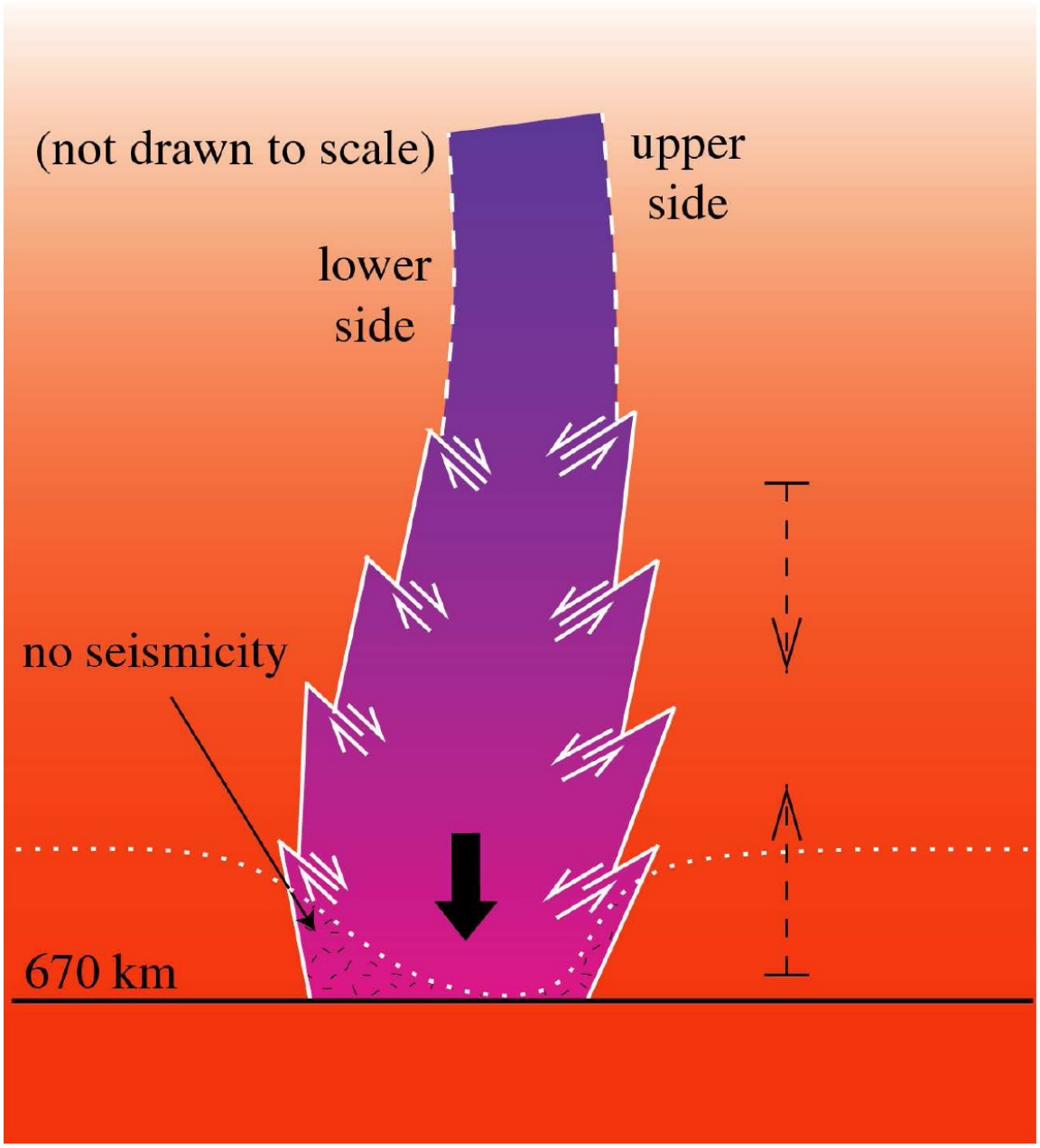
1.11: Profile JJ′ with relocated (red dot and red focal mechanism) and the CMT positions ›cal mechanism). Each line segment connects the focal mechanism with its hypocentral position ł and unrelocated). The earthquake of June 7, 1991 (060791) shows a significant shift upwards lower position where its focal mechanism is better explicable than at its CMT position (see

Open bars
T-axis
Solid lines
P-axis



Open bars:
T- axis
Solid line:
P-axis




(not drawn to scale)
upper side
lower side
no seismicity
670 km

H.-J. Schöffel and S. Das (1999). Fine details of the Wadati-Benioff zone under Indonesia and its geodynamic implications, *J. Geophys. Res.*, **104**, 13101-13114.

S. Das, H.-J. Schöffel and F. Gilbert (2000) Mechanism of slab thickening near 670 km under Indonesia, *Geophys. Res. Lett.*, **27**, 831-834.

S. Das (2004) Seismicity gaps and the shape of the seismic zone in the Banda Sea region from relocated hypocenters, *J. Geophys. Res.*, **109**.

S. Das and H.-J. Schöffel (2000) Accurate earthquake locations under Indonesia: implications for Wadati-Benioff zone shape, mantle dynamics and deep earthquake mechanism, in *Problems in Geophysics for the New Millennium*, Editrice Compositori, Bologna, Italy, 47-72.

In addition to these studies, ISC data has been used by us in the study of many large earthquakes to accurately relocate aftershocks, foreshocks and background seismicity and relate these to the main earthquake slip distribution.

Summary paper:

Das, S. and C. Henry (2003) Spatial relation between main earthquake slip and its aftershock distribution, *Rev. Geophys.*,**41**,1013, 2003.