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# 58. *Regional Study on the Characteristic Seismicity of the World.*

## *Part VI. Colombia, Rumania and South Sandwich Islands.*

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### Summary

Focal distribution of upper mantle earthquake nests in three seismic areas—in the northern part of Colombia, around the Carpathian bend in Rumania and in the northern part of the South Sandwich Islands arc—were studied with relation to the topographies around the areas. An inclined focal zone existing only in the upper mantle beneath the Oriental Mountain chain in Colombia was suggested to be a remnant of the lithosphere which underthrusted in the previous epoch.

Upper mantle earthquakes originating beneath the Carpathian bend distribute vertically along the NW-SE profile perpendicular to the axis of the Carpathian bend. This situation resembles that beneath the Hindu Kush. There are, however, almost no events in the crust above the upper mantle earthquake nest.

Foci distributions in the South Sandwich Islands region along the profiles perpendicular to the trend of the trench look like having characters different from those in other Island arc-trench regions. That is, the foci plane cannot be well recognized and foci do not penetrate so deep as is expected from the well developed trench.

The occurrence of upper mantle earthquakes in the northernmost terminal of the South Sandwich Islands arc is a quite peculiar one. Foci are gathering into a U shaped space beneath the area of about 1.3°×0.7° centering at 27.3°W, 56.1°S. Such focal distribution cannot be explained from plate tectonics associated with the Island arc-trench system.

### 1. Introduction

In general, physical properties in the upper mantle are inadequate for generating the earthquakes. Upper mantle earthquakes, however, are taking place and are quite active beneath restricted regions. The generations of these upper mantle earthquakes have been well explained by the underthrusting of lithosphere slabs due to the movements of the oceanic plates along their boundaries against other ones.

There are, however, several seismic regions with many upper mantle earthquakes for which the generations of these upper mantle events are difficult to relate to the movements of the plates which are considered to be going on in the present geological epoch. Upper mantle earthquakes in Hindu Kush and in North Burma are typical examples of such exceptional cases as given above.

Three seismic areas in Colombia, in Rumania and in the northern part of the South Sandwich Islands arc which are to be taken as one of a series of studies are other examples of the special cases just mentioned.

As in previous papers, earthquake data were taken from the Preliminary Determination of Epicenters by U. S. Coast and Geodetic Survey. The data cover the period from January 1964 to December 1969.

## 2. Upper mantle earthquakes in Colombia

Several upper mantle earthquake nests have been discovered in South America in the previous study.[2] Among them the northernmost nest in the northern part of Colombia which was denoted by N1 in the previous paper was the most remarkable and striking one. In the present paper, the seismic activity and its relation to topography surrounding that net will be studied again more deeply.

As was reported in the previous paper,[3] several local, well distributed stations surround the active area in Colombia. As is shown in another paper in this Bulletin,[4] the passive detectability in South America is one of the best, and foci of events having CGS magnitude $m$ as low as 4.3 are determined without omissions. Locations of the foci determined by USCGS in this area, therefore, are thought to be reliable.

Figures 1 and 2 give the epicentral distribution of shallow earthquakes ($d<100$ km) and the deep ones ($d\geqq 100$ km) for the northwestern corner of South America respectively. Epicentral distributions in the area south of latitude 6°N in these two figures reveal themselves as the first feature to be noticed, that shallow events of $d<50$ km mostly distribute off-shore of the western coast of Colombia while those deeper

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1) T. SANTÔ, "Regional Study on the Characteristic Seismicity of the World, Part 1. Hindu Kush Region," *Bull. Earthq. Res. Inst.*, **47** (1969), 1035-1048.

2) T. SANTÔ, "Characteristics of Seismicity in South America", *Bull. Earthq. Res. Inst.*, **47** (1969), 635-672.

3) *ibid.*, 2).

4) T. SANTÔ, "Regional Variation of the Passive Detectability of Earthquakes in the World", *Bull. Earthq. Res. Inst.*, **48** (1970), 1107-1119.

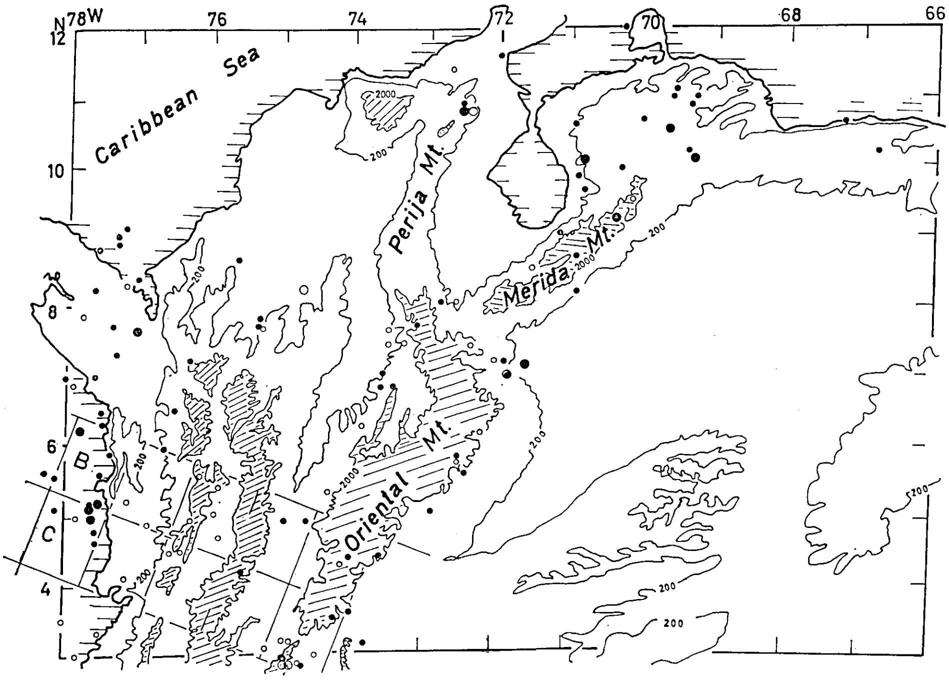


Fig. 1. Epicentral distribution of shallow earthquakes in Colombia. Filled circles: $d<50$ km. Open circles: $50\,\text{km}\leqq d<100\,\text{km}$. Large marks: $m\geqq5.0$. Small marks: $m<5.0$. Numerals in contour lines mean the heights in $m$. Hatched region is the mountainous one higher than 2000 m.

than 50 km spread widely into the mountainous regions (Fig. 2), and that the earthquakes of $100\,\text{km}\leqq d<150$ km concentrate into two small areas, one around 5°N, 76°W and the other around 3°N, 74.5°W.

Focal distributions of the earthquakes along the two profiles (B) and (C) perpendicular to the trend of the mountain chains are given in Fig. 3. This figure shows that there is a pair of focal zones in the foci distribution along the southern section (C) with inclinations of around 45°. In these two focal zones, the zone in the western side may be related to, but the eastern one beneath the Oriental Mountain chain cannot be related to the underthrusting of an oceanic lithosphere slab inside the land. In the profile (B), we can also recognize a vestige of the second foci zone as above, present beneath the Oriental Mountain chain.

In Fig. 2, a remarkably concentrated group of epicenters is seen around latitude 7°N and longitude 73°W, the central part of which has to be drawn schematically because so many events have taken place inside it. What was named the nest N1 in the previous paper was the group of events included in the space between 6.7°N–7.0°N, 72.9°W–73.2°W and the depth range from 150 km to 160 km.

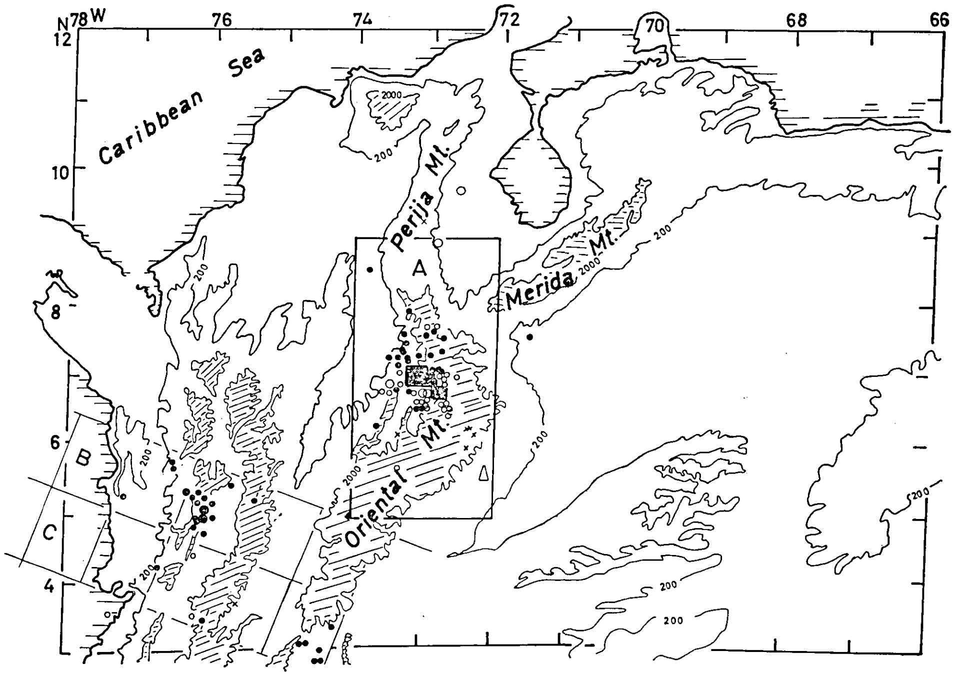


Fig. 2. Epicentral distribution of upper mantle earthquakes in Colombia. Filled circles: $100\,\text{km} \leqq d < 150\,\text{km}$. Open circles: $150\,\text{km} \leqq d < 200\,\text{km}$. Crosses: $200\,\text{km} \leqq d < 250\,\text{km}$. Open triangles: $d \geqq 250\,\text{km}$. Epicenters in the central part of the fringed area A are omitted because of so many epicenters. Numerals on the contour lines mean the heights in m.

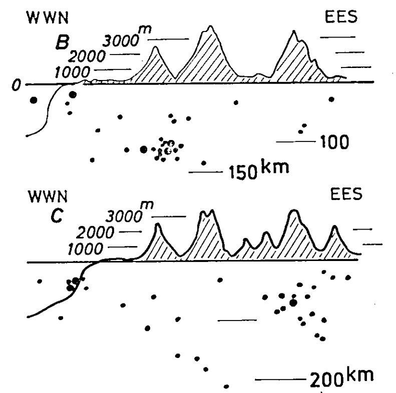


Fig. 3. Foci distributions inside the areas of (B) and (C) which were shown in Figs. 1 and 2 along the profile in WWN-EES direction. Large circles: $m \geqq 5.0$. Small circles: $m \leqq 4.9$. Topographies along the central axes are presented for comparison.

Figure 4 shows in detail the distribution of epicenters with various depth ranges inside 5°N–9°N and 70°W–74°W with the nest at its center. Even in this map, the frequency of the events in the small area of 6.8°N–6.9°N and 72.9°W–73.1°W was so large that the activity is represented by giving the numbers of the events in each $0.5° \times 0.5°$ mesh. 112 events in total have taken place during 72 months inside the area of $0.1° \times 0.15°$, that is approximately $10\,\text{km} \times 15\,\text{km}$. As is seen later, most of their foci have depths ranging between 150 km–170 km. The monthly frequency of the upper mantle earthquakes here is, therefore, estimated as about 1.5/(10×15×20) km³. The frequency (f) distributions within a certain magnitude ($m$) range in this small space were: $3.6 \leqq m \leqq 3.8$ ($f=7$), $3.9 \leqq m \leqq 4.1$ ($f=23$), $4.2 \leqq m \leqq 4.4$ ($f=25$), $4.5 \leqq m \leqq 4.7$ ($f=25$), $4.8 \leqq m \leqq 5.0$ ($f=14$), $5.1 \leqq m \leqq 5.3$ ($f=6$), and the largest one was $m=6.0$.

The focal distribution of the earthquakes projected on a profile along a line (A) of Fig. 4 within 50 km of its both sides is presented in Fig. 5. Details inside the open space are shown in the annexed figure. In the latter figure, foci look like being grouped into two by a somewhat poorly active space between them. The frequency distribution of the first group has a maximum depth around 160 km, while the latter one distributes much wider and flat down to a depth of near 200 km.

Summarizing, the foci distribute around an inclined straight line (dip angle of about 43°) and reach a depth of around 200 km with a nest beneath the western foot of the Oriental Mountain chain.

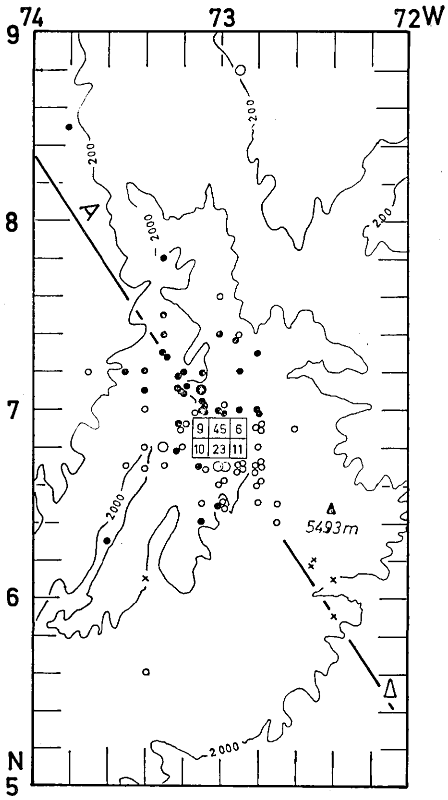


Fig. 4. Detailed distribution of epicenters of the upper mantle ($d \geqq 100$ km) earthquakes in and around the earthquake nest of Colombia. Activity of the events in the central part is presented by the frequency in each 1°×1° mesh. Location of the highest mountain de Cocuy (5493 m) is also shown by a filled triangle. Four different kinds of epicenter marks have the same meanings as were used in Fig. 2.

It must be noticed, however, that the distribution underthrusting into the continental side in this area has the following features which are quite different from those associated with the Island-arc.: In Island arc systems, the focal zone starts from shallow events off the coast, and the frequency $N$ of the events in the focal zone shallower than 150 km decreases with depth $Z$ by a general formula of $N=N_0 \exp(-Z/100)$, where $N_0$ is the frequency at the depth of 0 km.[5] The focal zone in

5) J. Oliver, L. R. Sykes and B. Isacks, "Seismology and the New Global Tectonics," *J. Geophys. Res.*, **73** (1968), 5855-5900.

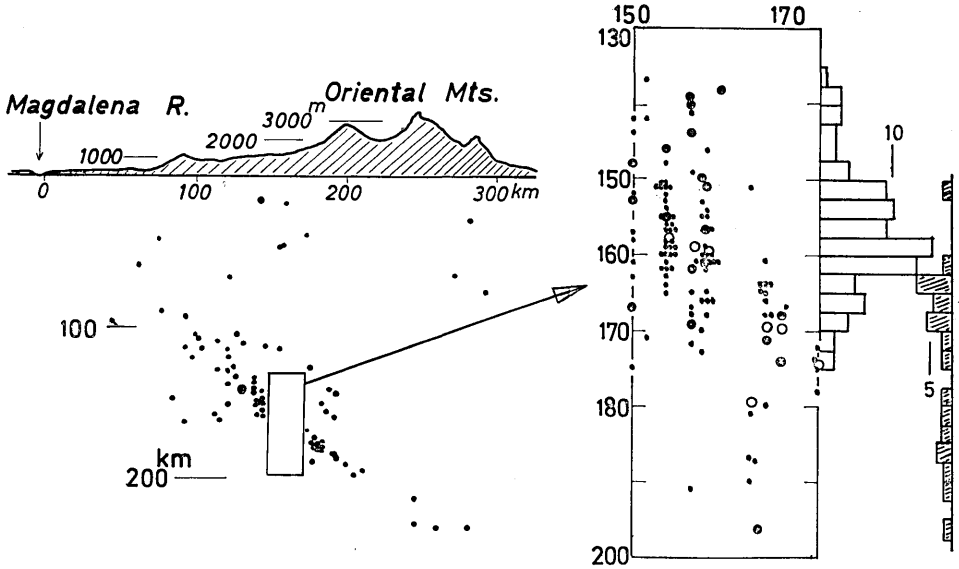


Fig. 5. Distribution of the foci being projected on a profile along a line A (Fig. 4). Detailed plottings of foci inside the open space and frequency distribution of foci in the shallower and deeper group versus depth are shown in the separate figures. In plotting, foci are separately plotted by shifting them in horizontal directions when they are reported to be at the same latitude and longitude. Large filled circles: $m \geqq 5.0$. Small filled circles: $m \leqq 4.9$. Open circles: Averaged depths of foci for several vertical lines. Topography along the line A is also shown for comparison. Rightmost histograms mean the frequency variations versus depth for shallower (open columns) and deeper group (hatched ones) of the foci inside the fringed space.

the present case, on the contrary, exists only in a depth range from 100 km to 200 km with a remarkable density of foci at a depth of 160 km $\pm$ 10 km. In Islands arc systems the focal zone is more clearly bounded at its oceanic side and more or less dispersed on the continental side especially in the shallow part, while in the present case, it does not form any straight boundaries but scatters into both sides with the most active center at a depth of around 160 km. In Island arc systems, the focal zone spreads laterally parallel to the arc, while in the present case, it exists with a lateral width of only about 50 km on average (see Fig. 4).

The distribution of foci in the focal zone associated with Island arc systems has been well explained by the underthrusting of the lithosphere slab beneath Island arcs which is now going on. The difference above given between the foci distributions associated with the Island arcs and with the present case, however, is too severe for making any effort to relate the mantle events beneath the Oriental Mountains in Colombia with the plate tectonics which has been suggested around the arcs.

Based on the study of seismicity and the focal mechanism of the earthquakes in Central America as well as in the Caribbean sea, a plate tectonics as is given in Fig. 6 has been suggested.[6] The presently active upper mantle events are located just around the junctions of the two boundary lines which divide the three plates of the Caribbean, the Americas and Nazca (see Fig. 6). Eastward and southward movements of the Caribbean and Nazca plates with respect to the Americas plate respectively have been suggested. But, they cannot explain the underthrusting focal zone of the present case. As is schematically shown in Fig. 7, epicenters of the upper mantle earthquakes spread just parallel to and just beside the deformed flow of the northern two mountain chains of Perija and Merida, which combine into one larger mountain chain of Oriental. Comparing the existence of the present special focal zone with the topography above mentioned, the stress which is still originating in the upper mantle events beneath the Oriental Mountain chain is surely due to the south-eastward pressure (an open arrow in Fig. 7), the same one which has deformed the topography. Judging from similar evidence on the eastern focal zoes along the profiles (B) and (C) in the southern part of the Oriental Mountains,

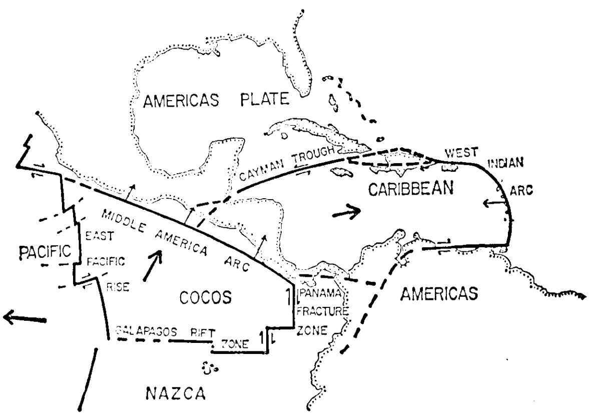


Fig. 6. Lithosphere plates and their relative movements with respect to the Americas. The large arrows show the direction of relative motion of plates at the boundaries. (After P. Molnar and L. R. Sykes).

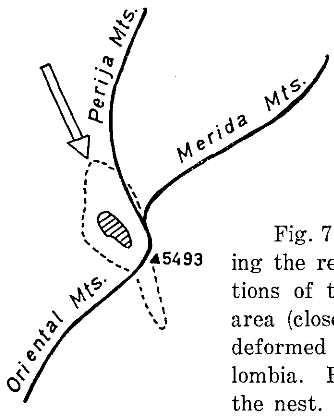


Fig. 7. Schematic figure showing the relation between the locations of the upper mantle seismic area (closed by broken curve) and deformed mountain chains in Colombia. Hatched region indicates the nest.

6) P. MOLNAR and L. R. SYKER, "Tectonics of the Caribbean and Middle America Regions from Focal Mechanisms and Seismicity", *Bull. Geol. Soc. Amer.*, **80** (1969), 1639-1684.

one suggestion may be that the focal zone in question is a remnant of the lithosphere slab which underthrusted into the mantle in the previous epoch. It still remains a question why the stress has remained only in the upper mantle in such a restricted space.

## 3. Isolated seismic active space in the upper mantle beneath Carpathian bend

On the Eurasia Continent, there are spaces in the upper mantle where earthquakes have been taking place quite locally. One is beneath Hindu Kush for which the seismicity has already been studied in one of the present series of papers. Another one is located in Rumania. As is seen in Fig. 8, the earthquakes have been taking place in a small area of approximately $0.3^{\circ} \times 0.5^{\circ}$ centering just at the corner of the bending mountain chains, where the Carpathian Mountains from north-west make

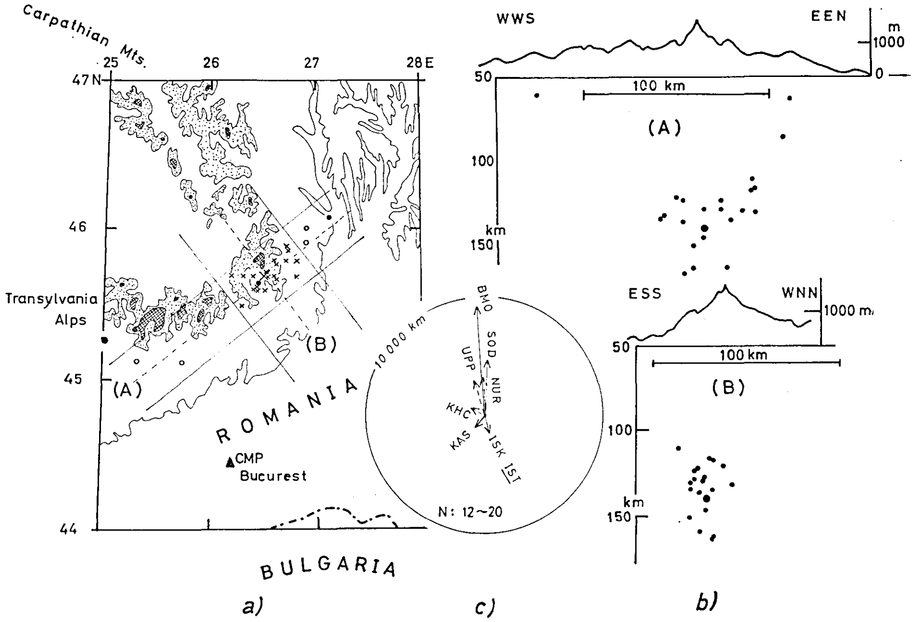


Fig. 8. a) Epicentral distribution of Rumania earthquake. Filled circles: $d<50$ km. Open circles: 50 km$\leqq d<$100 km. Crosses: $d\geqq$100 km. Filled triangles: The nearest station CMP. Dotted and hatched region means the mountainous one with a height of more than 1000 m and 1500 m respectively.

b) Foci distributions along the two profiles (A) and (B) which are shown in a). Horizontal scales are two times exaggerated with respect to the vertical ones.

c) Distances and azimuths of seismological stations around the central part of seismic area in Rumania, the data of which were constantly (solid arrows) or often (broken arrows) used by USCGS for determining the foci.

Table 1. List of stations the data of which are often used by USCGS for determining the foci of smaller shocks ($m=4.5$) in Rumania. Underlined: WWSSN. A: the stations almost always available. B: the stations often available. N: range of the total number of stations in average available after 1967.

| | Stations | | dist. | Az. |
|---|---|---|---|---|
| A | ISL | (Istanbul-Kandilli, Turkey) | 570 km | 161° |
| | KHC | (Kasperske Hory, Czechoslovakia) | 1,060 | 295 |
| | <u>NUR</u> | (Nurmiyarvi, Finland) | 1,600 | 356 |
| | SOD | (Sodankyla, Finland) | 2,400 | 360 |
| | BMO | (Blue Mountains, Oregon) | 9,400 | 335 |
| B | CMP | (Campulung, Rumania) | 155 | 245 |
| | <u>IST</u> | (Istanbul, Turkey) | 570 | 162 |
| | UPP | (Uppsala, Sweden) | 1,700 | 342 |
| | KAS | (Kastamono, Turkey) | 760 | 130 |
| | KJN | (Kajaani, Finland) | 2,000 | 12 |

N: 12～20

a *U* shaped turn to the Transylvania Alps. The frequency of the upper mantle earthquakes here, however, is not as high as in Colombia or in the Hindu kush. The total frequency during the period of six years from 1964 to 1969 is only 21, that is only three per year on the average. In spite of that, this small nest of upper mantle earthquakes is quite conspicuous because there are almost no shallow ones in and around the areas. As is shown in Fig. 8-c), nearby stations, the data of which are almost always contributing to USCGS, well distribute around the center of the seismic area. (Refer to Table 1). Passive detectability of the present area is also quite high and the foci of earthquakes with $m=4.5$ are determined here without omissions.[7)]

Foci distribution along two profiles (A) with NE-SW direction and (B) with NW-SE direction are shown in the right side of Fig. 8, respectively. They look similar to those beneath the Hindu Kush[8)] except for the very poor seismicity in the crust. Comparing them with the topography, it is also clear that the present nest has a strong relation to the pressure of a continental block from WWN direction, which is in good agreement with the study of the earthquake mechanism.[9)]

7) *ibid.*, 4).

8) *ibid.*, 1).

9) A. R. RITSEMA, "Seismo-Tectonic Implications of a Review of European Earthquake Mechanisms", *Geologische Rundschau*, **59** (1969), 36-56.

The generation of the upper mantle earthquakes beneath the Hindu Kush could be related to the underthrustings of two continental crusts, the Eurasian and Indian one, due to the northward drift of the latter.[10] In the present case of the upper mantle seismic activity beneath the Carpathian bend, however, we have still no other evidence on the collision of two continental blocks at the very same area. It is still an open question why the horizontal stress is now acting at the depth of the upper mantle only.

## 4. A nest of upper mantle earthquakes in the South Sandwich Islands arc

An upper mantle earthquake nest was also found beneath the ocean, near the northernmost terminal of the South Sandwich Islands arc. This is seen in Fig. 9 which presents the epicentral distribution of upper mantle

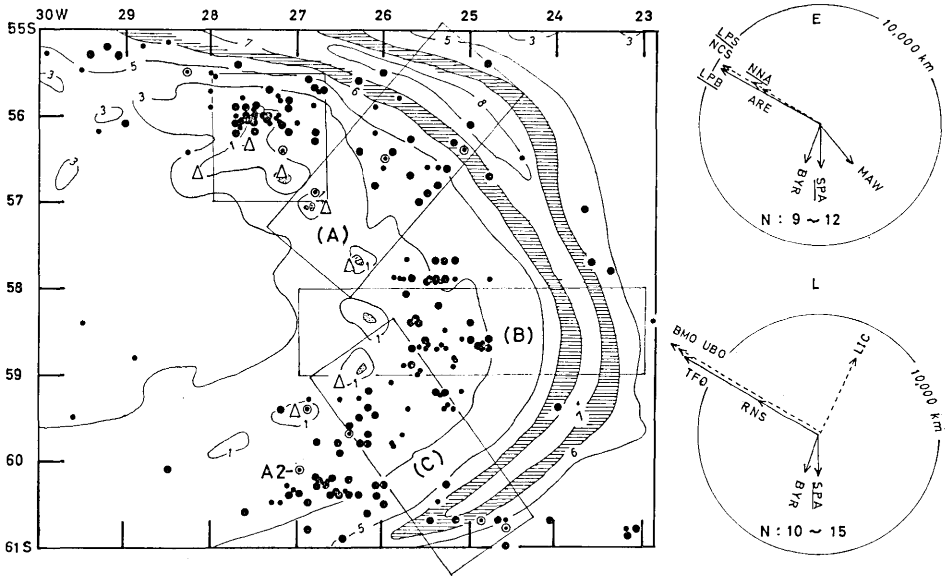


Fig. 9. Epicentral distribution of earthquakes in the South Sandwich Islands region shallower than 50 km. Double circles: $m \geqq 6.0$. Large circles: $m \geqq 5.0$. Small circles: $m < 5.0$. Open triangles: Locations of active volcanoes. Numerals on contour lines; Depths of the sea in km. A2 means the main shock ($m = 6.2$) which induced 20 aftershocks in the South-eastern area. Solid and broken arrows in the annexed figure show the directions and distances of the stations in two different periods $E$ and $L$ belonging to groups $A$ and $B$ given in Table 2.

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10) *ibid.*, 1), or

T. SANTÔ, "On the Characteristic Seismicity in South Asia from Hindu Kush to Burma", *Bull. Intern. Seism. and Earthq. Engin.*, **6** (1969), 81-93.

events deeper than 100 km. The nest is located around latitude 27.3°W and longitude 56.1°S inside the area of approximately 0.3°×1.0°.

The situation of passive detectability of the foci in the South Sandwich Islands region must be mentioned here. There are no nearby stations. As is seen in Fig. 9, even the nearest stations are on Antarctica to which the distances are around 4000 km (Table 2). This condition makes the detection of smaller seismic events in the South Sandwich Islands region difficult. Actually, as is seen in another paper,[11] the value

Table 2. List of stations the data of which were frequently available to USCGS for determining the foci of smaller events ($m \leq 5.2$) in the South Sandwich Islands region.*

| | Stations | | dist. | Az. |
|---|---|---|---|---|
| **E** | | | | |
| A | SPA | (South Pole, Antarctica) | 3,700 km | 180° |
| | BYR | (Byrd, Antarctica) | 4,000 | 197 |
| | MAW | (Mawson, Antarctica) | 4,500 | 140 |
| | LPB | (La Paz, Bolivia) | 9,600 | 300 |
| B | ARE | (Arequipa, Peru) | 5,600 | 301 |
| | NNA | (Nana, Peru) | 6,500 | 300 |
| | MUN | (Mundaring, Australia) | 9,600 | 150 |
| | NCS | (Nueva, Concepcion, El Salvador) | 9,600 | 302 |
| | LPS | (La Palma, El Salvador) | 9,700 | 301 |
| | N: 9∼12 | | | |
| **L** | | | | |
| A | SPA | (South Pole, Antarctica) | 3,700 | 180 |
| | BYB | (Byrd, Antarctica) | 4,000 | 197 |
| | PNS | (Penas, Bolivia) | 5,900 | 302 |
| | TFO | (Tonto Forest, Arizona) | 12,700 | 295 |
| B | ARE | (Arequipa, Peru) | 5,600 | 301 |
| | LIC | (Lamto, Ivory Coast) | 7,200 | 25 |
| | LPB | (La Paz, Bolivia) | 9,600 | 300 |
| | UBO | (Uinta Basin, Utah) | 13,500 | 296 |
| | BMO | (Blue Mountains, Oregon) | 14,300 | 295 |
| | N: 10∼15 | | | |

* E: earlier period (1964). L: later period (1968). Underlined station: WWSSN. N: range of total numbers of stations in average. A: stations almost constantly used. B: stations often used.

11) *ibid.*, 4).

of $m_c$, the smallest magnitude of the events the foci of which have been determined without omissions by the surrounding stations, is as large as 5.3 for the present region. This situation is reflected on the epicentral maps in which the number of small circles corresponding to the events of $m<5.0$ is remarkably smaller if compared with the large ones. This means that if there were nearby stations, the epicenters represented by small circles might distribute much more densely.

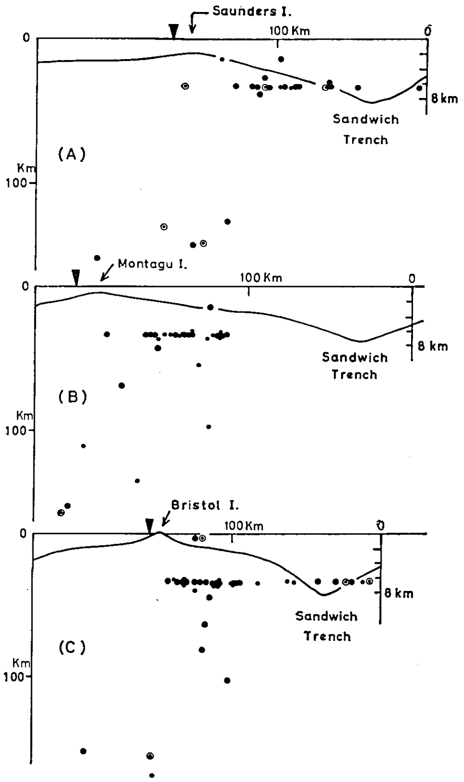


Fig. 10. Foci distributions being projected along the central axes perpendicular to the trending of a well developed trench in three areas (A), (B) and (C) shown in Fig. 9. Positions of the active volcanic belt are shown by solid triangles. Marks of foci have the same meanings as were used in Fig. 9. Vertical scales on the left are for the depth of foci and that on the right for sea depth.

Foci distribution in the areas (A), (B) and (C) along the axise perpendicular to the trend of the trench are shown in Fig. 10. Because of rather scanty data on the smaller events in the mantle, it is still hard to recognize any clear foci zone underthrusting into the mantle which is a typical feature of Island arc-trench systems. But, even if the bad condition of detecting the smaller events in this region is taken into account, it can be concluded that the length of the underthrusting lithosphere slab here is short and reaches only to a depth of around 100 km. A linear relation has been found between the length of the underthrusting lithosphere and its slide rate.[12] The slide rate of the lithosphere plate at the South Sandwich Trench was calculated slow as 2–3 cm/year,[13] which is surely reasonable for the length of the slab underthrusting the trench. It looks strange to the present writer, however, that such a

12) *ibid.*, 5).

13) X. Le PICHON, "Sea-Floor Spreading and Continental Drift," *J. Geophys. Res.*, **73** (1968), 3611–3697.

slow rate of underthrusting and such a short thrust could have formed a trench as deep and large as the Sandwich Trench. It is more understandable that a greater rate of underthrusting would make the trench deeper. This suggestion was actually clarified in some trench regions.[14]

From the view-point given above, a poor lithosphere slab underthrusting into the South Sandwich Islands region is quite a peculiar phenomenon.

In Fig. 9, we can see a group of shallow earthquakes in the northernmost terminal of the seismic zone which run along a curve parallel to the trench of the well developed northern trench. It is interesting that almost exactly beneath the same area, many upper mantle earthquakes have also been taking place, which is well recognized in Fig. 11.

A detailed epicentral distribution of earthquakes inside the area N in Fig. 11 is presented in Fig. 12. The earthquakes distribute wider to the EW direction almost parallel to the trend of the trench in the nor-

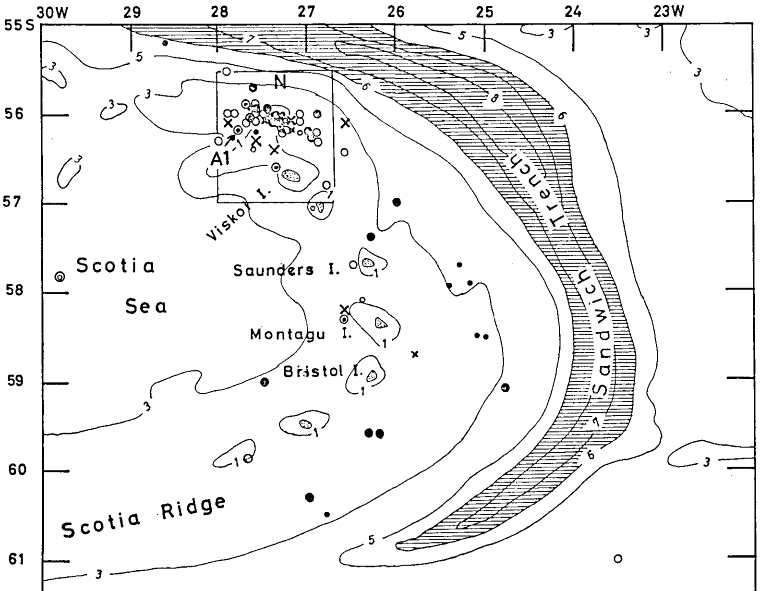


Fig. 11. Epicentral distribution of earthquakes with the depth range from 50 km to 100 km (filled circles), from 100 km to 200 km (open circles) and deeper than 200 km (crosses). Size of circles has the same meaning as was used in Fig. 9. A1 means the epicenter of main shock ($m=7.5$).

14) T. SANTÔ, "Regional Study on the Charactereristic Seismicity of the World. Part III. New Hebrides Islands Region," *Bull. Earthq. Res. Inst.*, **48** (1970), 1–18.

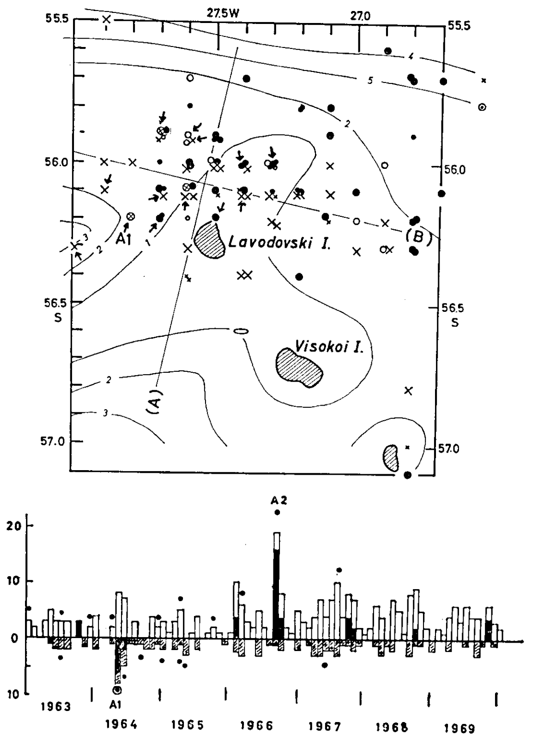


Fig. 12. Upper map; Detailed locations of epicenters in the area N which was presented in Fig. 10. Filled circles: $d<50$ km. Open circles: $50\leqq d<100$ km. Crosses: $d\geqq 100$ km. Largest open circles with crosses: $m\geqq 6.5$ deeper than 100 km. A1: Main shock ($m=7.5$) which induced 11 aftershocks (indicated by small arrows). Numerals in contour lines: depth of the sea in km.

Lower diagram: Comparative figure showing the monthly variations of the frequency of the earthquakes in the total area (open columns above) and in the area N (hatched columns below). Filled circles indicate the occurrences of large ($m\geqq 6.0$) events in the area N (below) and the other region (above) respectively. Occurrences of two mainshocks A1 and A2 are also indicated. Filled columns show the frequency of inductive events.

thern part. In the lower diagram, the monthly seismic activity in the area N (hatched column) is compared to the total seismicity (open column). 98 events have taken place in the area N against 391 events counted in the total area. There was a great event with $m$ of 7.5 in this area at a depth of 120 km (May 26, 1965) which induced 11 aftershocks (Table 3). It is worthy to remember that such great events as $m=7.5$ with aftershocks still took place even in such a depth as 120 km, though the frequency of aftershocks is smaller and the duration of the aftershock sequences is relatively shorter than for those associated with shallow events of similar magnitude.

Foci of the earthquakes inside the area N are projected along two sections (A) and (B), the former being parallel to the trend of the northern trench and the latter perpendicular to it (see Fig. 12). They distribute within the U shaped space having a nearly vertical axis. (see Fig. 13). The concentration of the plots along the depth of 33 km is insignificant, because the depth determinations are automatically restricted to 33 km or normal depth in the cases if any point in the depth computation goes above the reference sphere or if the unrestricted depth computation is unsatisfactory and in the judgement of the review-

Table 3. Aftershocks associated with the Main shock ($m=7.5$, $d=120$ km) of May 26, 5965.

| Date | Origin Time | Epicenter $\lambda$ | Epicenter $\varphi$ | Depth (km) | Mag. ($m$) |
|---|---|---|---|---|---|
| May 26 | $10^h\ 59^m\ 12.3^s$ | 56.2° S | 27.8°W | 120 | 7.5 |
| | 12 23 28 | 56.1 | 27.7 | 149 | 5.4 |
| | 15 42 34.0 | 56.1 | 27.4 | 82 | 5.4 |
| 27 | 00 56 42.5 | 56.1 | 27.6 | 105 | 5.6 |
| 29 | 09 04 27.1 | 56.2 | 27.7 | 33 | 5.8 |
| | 14 45 50 | 56.1 | 27.9 | 170 | 5.2 |
| | 15 33 06 | 56.3 | 28.0 | 120 | 5.7 |
| June 05 | 04 08 30.6 | 56.2 | 27.5 | 33 | 5.3 |
| 06 | 22 01 45.2 | 56.0 | 27.4 | 33 | 5.3 |
| 11 | 10 55 06.2 | 56.0 | 27.3 | 33 | 5.8 |
| | 21 28 08.2 | 55.9 | 27.7 | 135 | 6.1 |
| 26 | 01 32 51.5 | 55.9 | 27.6 | 55 | 5.5 |
| July 12 | 21 08 52.6 | 55.9 | 27.6 | 135 | 5.2 |

ing geophysicist the earthquake probably has shallow ones.

Foci contain six events with $m\geqq 6.0$, which tells that the material in this U shaped space reaching down to a depth of nearly 200 km has still a large capacity for storing the stress energy. In the same figure, the foci of the main shock and the associated aftershocks are distinguished. The events were considered as aftershocks because of the timal and areal relation to the main shock, as usual for aftershock sequences (see Table 3). Figure 13 shows, however, that their depth distribution is much wider than the horizontal distribution and the foci occupy almost the whole seismic depth range down to 150 km. This fact is also a remarkable one.

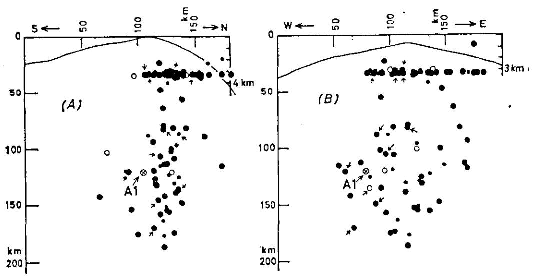


Fig. 13. Foci distributions of earthquakes in the area N being projected on the two sections (A), perpendicular to the trend of the trench, and (B), parallel to the trend of the trench (see Fig. 11). Large shocks of $m\geqq 6.0$ are indicated by open circles. A1 is the main shock ($m=7.5$) which induced aftershocks shown by small arrows.

It is still hard to give any suggestion as to the kind of mechanical movement which might have caused such upper mantle earthquakes in such a U shaped space just beneath the northernmost terminal of the South Sandwich Islands arc.

## 5. Conclusions

A study was made on three upper mantle earthquake nests existing in Colombia, Rumania and the northern part of the South Sandwich Islands arc. The following characteristics were recognized.

1. There is a conspicuous epicentral group of upper mantle earthquakes centering at 73.1°W and 6.9°N, in the northern part of Colombia. This group of upper mantle epicenters spreads just parallel to and just beside the deformed trend of the mountain chain of Perija and Merida, which combine into one greater mountain chain of Oriental (Figs. 2 and 7).
2. The foci of the earthquakes are inclined to the south-east with the dip angle of about 43° (Fig. 5). The foci distribution, however, has several features different from those associated with the Island arc-trench systems. It is hard to relate the occurrences of these upper mantle earthquakes to plate tectonics which has been suggested around the area in question. Judging from the evidence given in item 1, the cause of these earthquakes is suggested as being due to the stress which deformed the mountain chains (Fig. 7).
3. Similar patterns of foci distribution were also found beneath the Southern Oriental Mountain chain around longitude 3°$\sim$5° N (Fig. 3).

Together with the evidence given above, they may be a remnant of the lithosphere slab which had underthrusted beneath the Oriental mountains in the previous active epoch of sea-floor spreading.

4. A small epicentral group of upper mantle earthquakes also exists in Rumania. It is located just at the corner where the Carpathian Mountains make a U shaped turn and change into the Transylvania Alps (Fig. 8).

Foci in this case distribute vertically along the NW-SE profile perpendicular to the axis of the bend, which resembles those beneath the Hindu Kush. A remarkable difference, however, is that there are almost no shallow earthquakes in and around the area (Fig. 8).

5. The foci distributions along a few profiles perpendicular to the South Sandwich Trench show a feature somewhat different from those associated with other Island arc-trench systems. That is, the focal zone do not clearly appear and the foci do not penetrated as deep as can be expected from a trench so well developed as the South Sandwich Trench. (Fig. 10).
6. There is a group of epicenters of both shallow and deep earthquakes in the northernmost terminal of the South Sandwich Islands arc. (Figs. 9 and 11). The seismic space beneath there forms a U shaped pocket. One-fourth of the events in the South Sandwich Islands region have been

taking place in that space of approximately 50 km × 100 km × 200 km. This lithosphere has a large capacity for storing the stress energy, and ten events with $m$ larger than 6 are contained in it (Fig. 12).
7. The largest ($m=7.5$) upper mantle earthquake in the U shaped seismic space given above took place at a depth of 120 km. It reduced eleven aftershocks which distributed wide in a vertical direction (Table 3, Fig. 13).

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# 58. 世界の特殊な地震地区の活動について

## (其の六) コロンビア，ルーマニアおよび南サンドウィッチ諸島

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現在のプレート・テクトニクスでは説明がむづかしい場所と震源分布をもつマントル地震活動地区が世界中には特に大陸内部に存在する．たとえば，ヒンズー・クシや北ビルマのそれらもその代表的な例であった．本篇で取扱った三つの地区のマントル地震も，まさにその例といえる．

南米大陸にはいくつかのマントル地震の巣があることを，以前述べたことがあるが，そのうちで，コロンビア北部のそれは，最も顕著なものである．場所は，オリエンタル山脈が東南方向に大きく変形したあたりで，震源もまたその方向に伸びて，約 45° の傾きで斜めにおちこみ，その中央部ではかなり高い密度（10 km×15 km×20 km の空間内で月に 1〜2 回）地震が起こっている（第 4 図）．この震源域は，板状ではなく，中央がふくらんだ棒状のもので，（第 5 図），場所といいその方向といい，また震源の分布状態といい，少くとも現在のプレートの動きからは説明がむづかしい．強いて想像すれば，かってこのあたりに，現在とは異ったプレートとその動きがあって，その名残が何らかの原因で現在マントル中に棒状の震源域として残っているのだと考えるしかない．しかしそれにしても，なぜ浅い地殻内のストレスだけ消えて，マントル上部だけにそれが棒状に残っているのかは分らない．

ルーマニア東部，カラパチア山脈の大きな彎曲部の頂点に当るところにも，マントル地震の密集した巣がある（第 8 図）．ここでの震源分布は，その彎曲した山脈の稜線に直角な面内で垂直であって，浅い地震がない点を除いてはヒンズー・クシの地震の震源分布に似ている．しかし，ヒンズー・クシの場合のように，インド大陸の合併に相当する過去の事件を想像しうる他の根拠がここにはないので，この震源分布の原因をつきとめることは，今の段階では困難である，

南サンドウィッチ諸島に沿った地震帯の北端にあるマントル地震多発地区における震源も，ほとんど垂直に分布している．ここでの震源は，南北の切口で巾約 50 km，東西の切口で巾約 100 km の中におさまっていて（第 13 図），南サンドウィッチ周辺の全地震数の約 1/4 を含んでいる．また，この中には，$m\geqq 6.0$ のマントル地震が 10 箇もあり，$m=7.5$ という大きな地震と，それに伴う 10 ヶ余りの余震を含んでいる（第 3 表）ことも，この深さでの物性を考慮するばあいに見おとせない事実である．

サンドウィッチ海溝におちこむプレートの速度はわりにおそく（年に 2〜3 cm），震源面のおちこんでいる深さも 100 km 内外にすぎない（第 10 図）．にもかかわらず海溝の規模は実に雄大で深い．海溝は，プレートにひきずりこまれて出来たものと考えたいし，それを裏付ける事実も他では見られるのだが，ここで得られた上の事実はその点では矛盾している．

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