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STRUCTURE OF A SEISMIC VELOCITY DISCONTINUITY AT A DEPTH OF THE ORDER OF 600 KM - EXAMPLE BENEATH FRANCE

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Seismologists are much more attracted by the studies of seismic travel times than by studies of seismic amplitudes. This is mainly due to the fact that amplitude variations may be very large and dependent on many parameters. There is no "smoothing law" for amplitude comparable to Fermat Principle. But an array may be a very efficient tool to explain at least some of the variations of seismic amplitudes. Two rays originating from the same source and recorded in two stations the distance between which is small compared to the epicentral distance, differ only by the part of their path which is in the vicinity of the stations. It is then possible to explain the variation of amplitude by the structure of the earth's crust and mostly by the depth of Mohorovicic discontinuity (e.g., Mechler, 1969).

Let us describe such an amplitude anomaly which we observed in France. In one of our stations, Toulx-Ste-Croix (TCF), we recorded one event from the Semipalatinsk area (U.S.S.R.) and another from Lop Nor (China). As seen from the station, the two epicenters are nearly in the same azimuth (1^{o} difference) and the Chinese one is roughly 1000 km farther away than the first one. The amplitude of the Russian event, compared to the mean amplitude recorded in all our stations in France is 0.4, the same figure for the Chinese event is 3.25. We are facing an amplitude anomaly which can be explained neither by a change in the source due to the definition of relative amplitude nor to the immediate vicinity of the station TCF, the two rays being too close one to the other near the station. It has been demonstrated that it could be possible to explain such anomalies by changes in the depth of the well-known seismic velocity discontinuity at a depth of the order of 600 km (Mechler and Rocard, 1970).

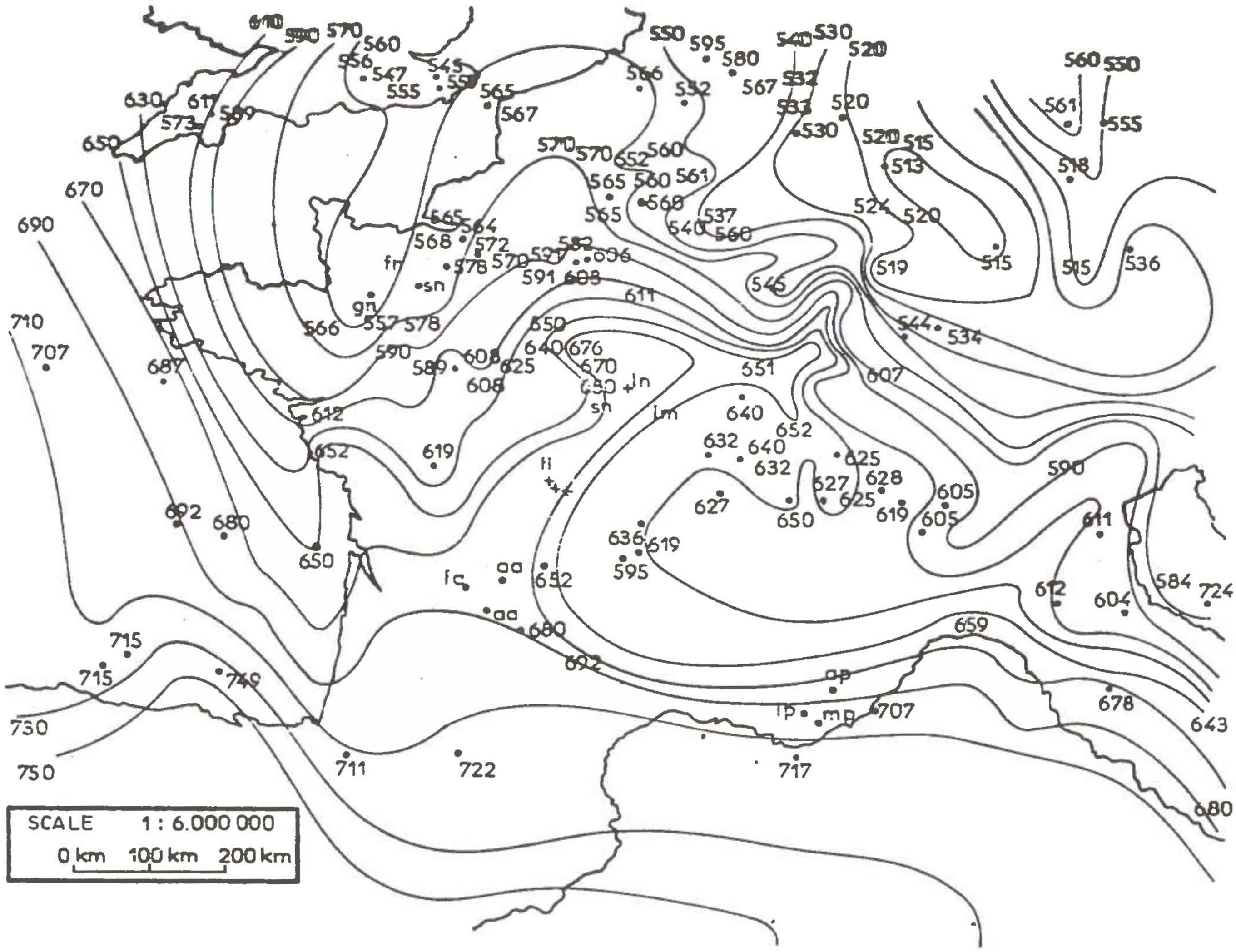

Fig 1. Depth of the asthenosphere beneath France according to seismic readings from French Seismic Network.

We assume, as a heuristic hypothesis, that the velocity discontinuity around 600 km may change in depth from one point to the other and we will se the consequence of this hypothesis.

First we have to draw the map of this discontinuity. We studied all well-recorded events of our stations in France during two years and computed the time terms, i.e., observed time minus computed time of propagation. Our seismic array is formed by five tripartite stations (distance between main and peripheral stations is of the order of 30 km, between two triangles 300 km). In order to decrease the contribution of crustal structure we use the mean value of time terms on a triangle and compare the mean time terms between triangles.

Fixing the depth of the discontinuity at the place where a ray coming from north (Aleutian) across the discontinuity before arriving at our triangle from Morvan (main station LOR) at 560 km, we were able to draw the map of Fig 1.

We have now to study the consequence of this hypothesis which may seem too arbitrary.

1) The depth in the northeast of France (southern part of Germany is of the order of 550 km everywhere, this fits with the value published by Mayer-Rosa and Ansorge (1968)). The initial depth of 560 km was fixed for this purpose.

2) We observed a "closure" of the map. The same depth may be found at the same point using two P-waves from different origins, recorded in different stations but crossing the discontinuity at the same point.

   We tried for different "initial depths", this closure was at its best for 560 km as explained before. This also gives us an idea of the precision we may expect from this map which is of the order of ± 10 km in depth.

3) Many other models may explain the travel time anomalies we observed. In order to substantiate our hypothesis we will study the amplitude of the recorded wave. We first notice the "Toulx-Ste-Croix effect". In order to explain it by a focalization of waves by changes in the depth and curvature of a seismic velocity discontinuity, which has to be deep enough for the rays to be separated. At least the "Fresnel zone" of the rays has to be disconnnected. It is very easy to show that the minimum depth for the discontinuity has to be 450 km. This excludes the first known discontinuity at 350 km and explains the choice of the second discontinuity around 600 km in our heuristic hypothesis.

4) It is also possible to correlate the recorded amplitudes and the obtained structure for the 600 km discontinuity. Fig 2, 3 and 4 show some results in different azimuths. The relative amplitude plotted is recorded amplitude of the wave divided by the mean amplitude of the same P-wave over all of France; it is therefore possible to compare different ray paths. It is clear that we have a nice correlation between small amplitudes and defocusing dioptres.

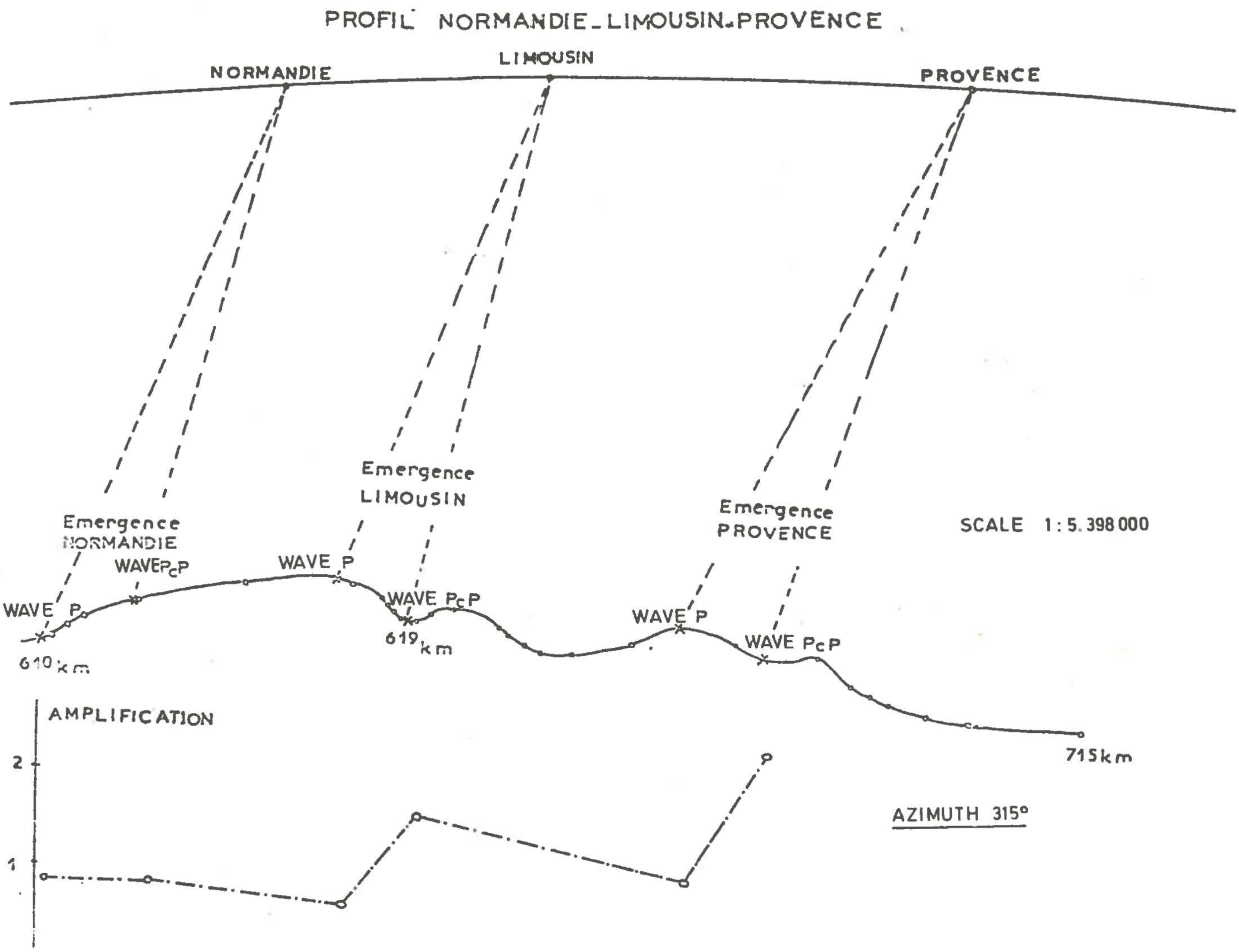

Fig 2. Nuclear explosions in Nevada.

It is possible to compute the focusing or defocusing effect and compare it with the observed amplitude. The results are surprisingly good even with very rough assumptions.

5) It is possible to prove our hypothesis in a completely different way. It was possible to invert the travel time curves versus distance for two seismic areas, both between 17° and 25° from France: Western Turkey and Eastern Mediterranean. The results were as follows: In both cases the first discontinuity is at 388 km, the second discontinuity is at 608 for Turkey and 627 for Eastern Mediterranean; our map gives for these two places respectively 610 and 630 km, that is, taking into account the accuracy, exactly the same values.

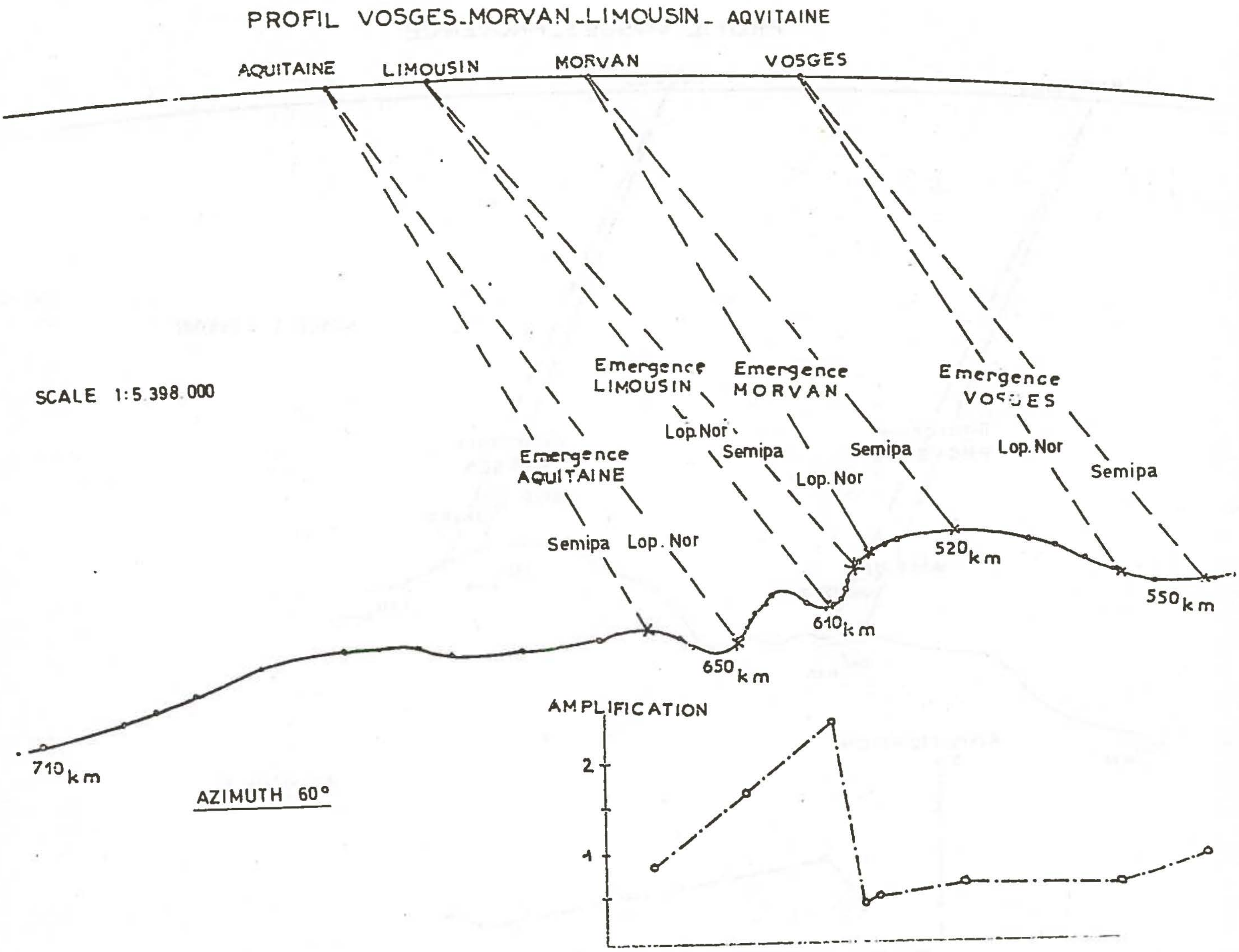

Fig 3. Nuclear explosions in the Semipalatinsk and Lop Nor areas.

This presentation has voluntarily been limited to a short summary of the work we did on this subject. We have not developed any computation and evaluation on other topics related to this. For example, the large descent of the discontinuity should be accompanied by a change in density and henceforth by a change in the gravimetric field. An order of magnitude of this effect is 100 mgals which is possible to compensate to obtain a smaller isostatic anomaly. Nor have we presented any explanation which can be found in the plate tectonic structure of this part of the world. For a more complete description, see Beaufils et al, 1970, and Mechler et al, 1972.

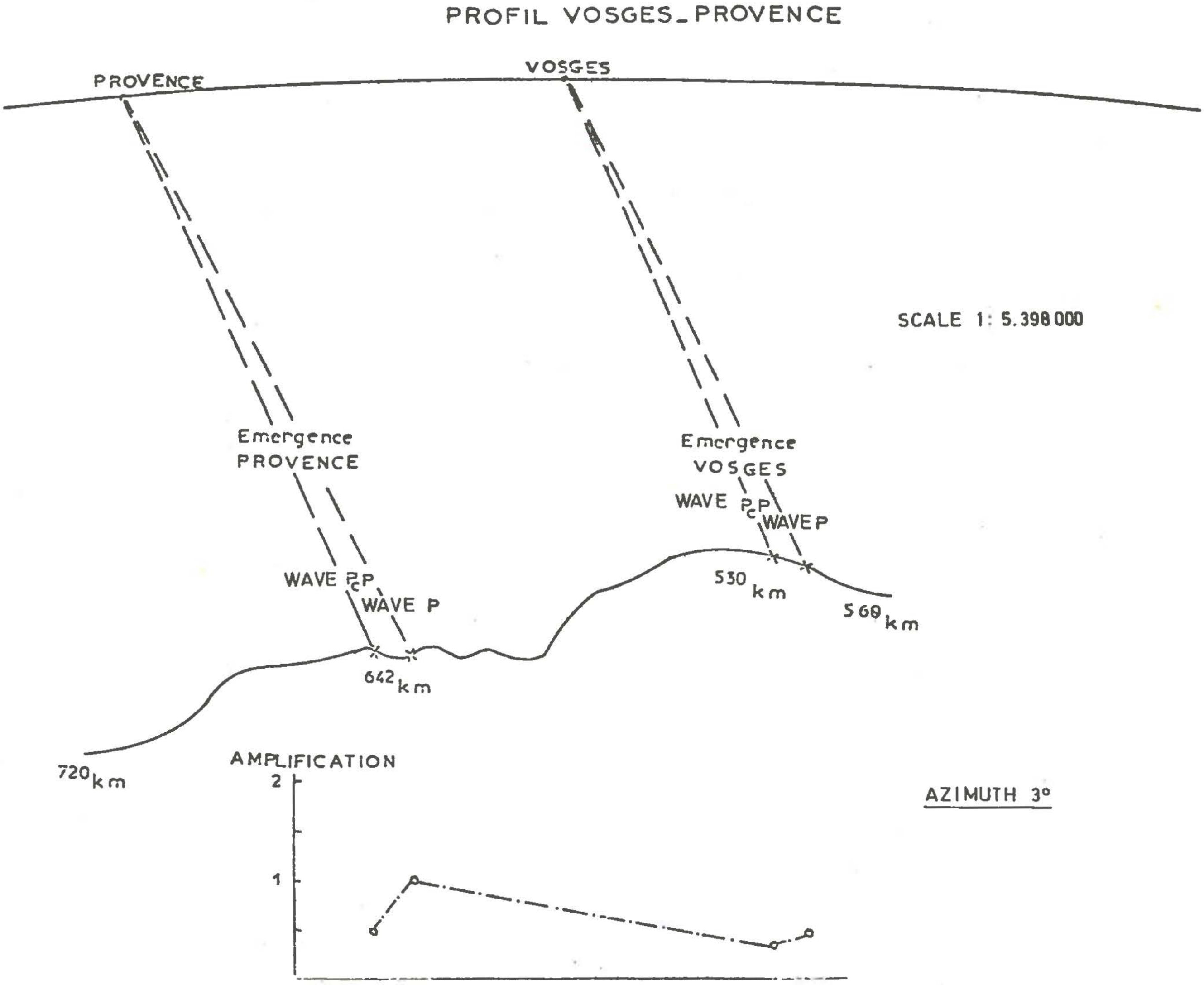

Fig 4. Nuclear explosion in the Aleutian Islands.

Nevertheless we think that our model, however crude it may be, does explain different anomalies in travel times and in amplitude and can be extended to other areas of the world and can be a first approximation for our understanding of the real structure of the world and its departure from the spherical symmetry usually accepted for the computation of models.

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