4.9.1. GEODETIC DETERMINATION OF GEODYNAMICS AROUND THE ADRIATIC PLATE

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4.9.1.1. Introduction

The meeting-points of tectonic plates are often the focal points of earthquakes. The earthquakes are a consequence of movement of the plates. On that occasion immense quantities of energy used to be released, depending on the resistance between the plates. Very often not only a contact of two tectonic plates is present but there are some micro-plates between them with their own movement resulting from the pressures of the macro-plate. Such an example is the Adriatic plate between the African and European plates.

Fig. 4.9.1.1. (Moores, Twiss, 1995) represents the Adriatic plate that is not only spread under the Adriatic Sea but is extended far away towards the Padan lowland. At the Northern part of that micro-plate there is a focal point of very strong earthquakes. There, the African plate exerts pressure against the European plate. So, in the recent history, a series of earthquakes occurred in the Northern Italy, Slovenia (let us mention only the most important ones: the Idrian and Ljubljana earthquakes), and the focal points continue in Croatia, in Bosnia and Herzegovina, and further away.

The tectonic plates are dynamic geological units changing their position in time. In order to recognise events in the past and possibly forecast the future ones it is indispensable to know the directions and speed of the tectonic plates movement. In the past it was practically impossible. Only the advent of the electronic distance meters, Global Positioning System (GPS) in the first place, made it possible to determine neotectonic movements with sufficient accuracy. The high precision of the measurements has substantially shortened the time interval in which these movements could be defined.

Through the set-up of the modern European GPS network (EUREF) the possibility to observe neotectonic movements along the Adriatic plate was provided.

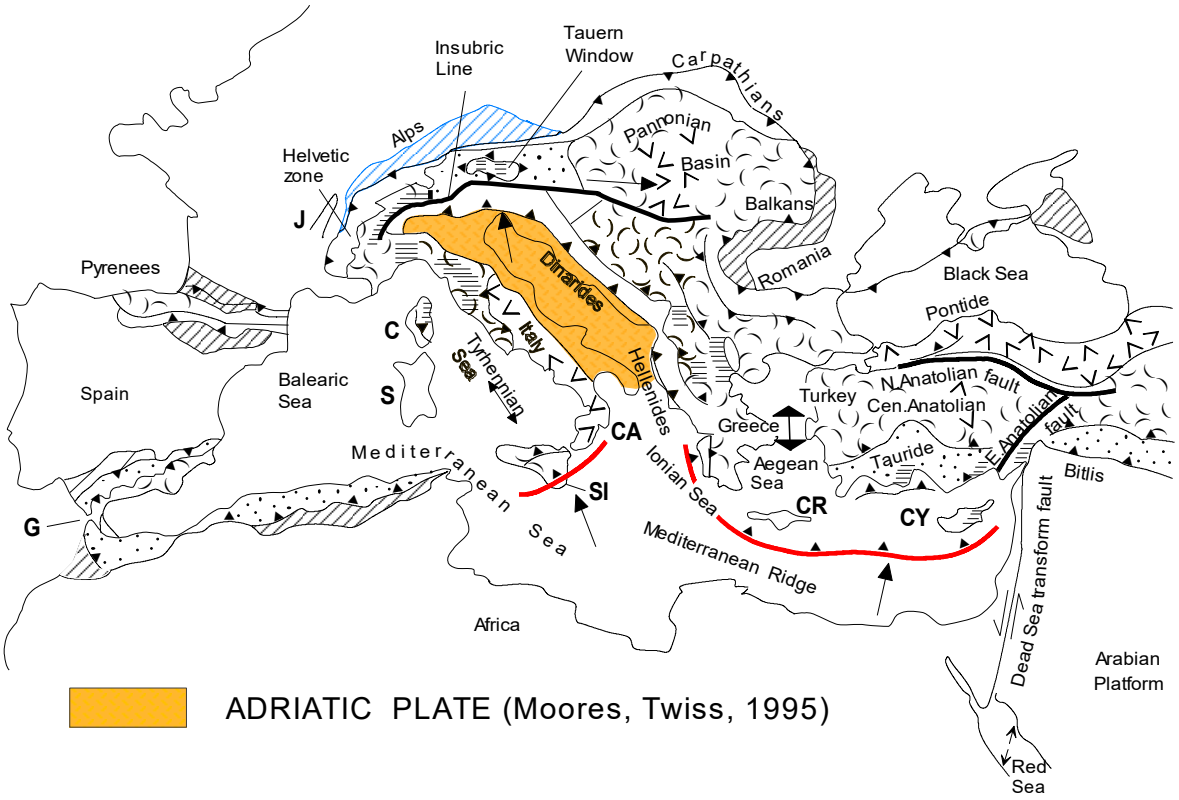

Fig. 4.9.1.1. Adriatic plate

4.9.1.2. Measurements in Italy and Croatia

Italy has primarily co-operated in the CERGOP campaign within Central Europe. In addition, they have a series of smaller local networks in the vicinity of epicentres of heavier earthquakes that have occurred latterly. Also important is the co-operation with Austria and Slovenia in the region where three countries meet. Mainly, they carry out researches at the west part of the Adriatic plate.

Much more systematically are performed the measurements in Croatia. The first GPS measurements were carried out in Croatia during the country's incorporation into the European coordinate system. However, very soon it became obvious that the number of GPS points was insufficient, and they were not arranged at appropriate places. For that reason the GPS measurements from Slovenia over Croatia along the Adriatic plate have been combined within CRODYN. So far two measurement campaigns have been carried out: in 1994 and 1996. The results are astonishing. If it is understandable that the Adriatic plate is split into eastern and western parts, the CRODYN results indicate that the eastern part is split into two parts as well.

In Fig. 4.9.1.2. are visible various deformations at the eastern and western part. Consequently, there are at least two parts with absolutely detached kind of behaviour. Similarly different vectors of horizontal movements, established by the same research, are shown in Fig. 4.9.1.3., too, also affirming the above supposition.

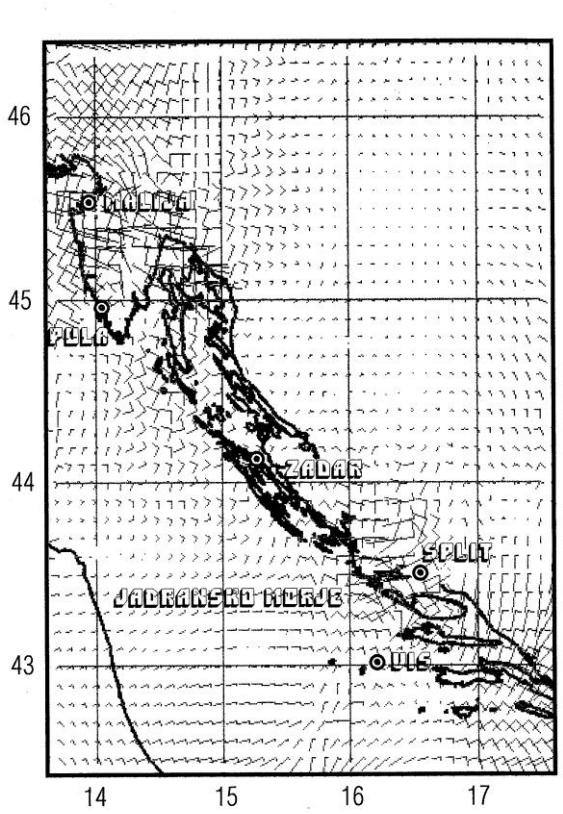

Fig. 4.9.1.2. Deformations along the Adriatic plate

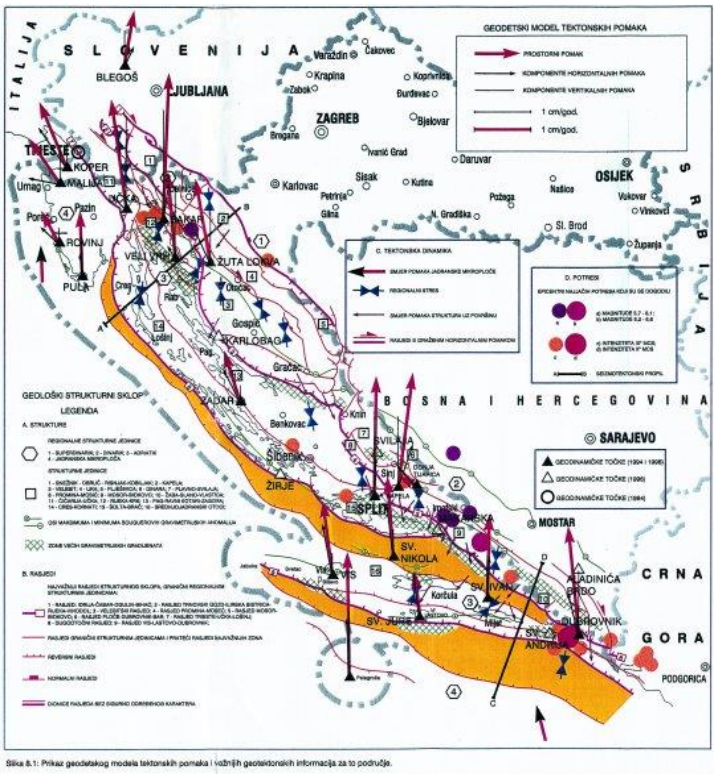

Fig. 4.9.1.3. Vectors of movements, established through the CRODYN campaign

Some anomalies of movements in Istria should be pointed out, at the north-west of the plate, differing from the other movements. This could result from the limited accuracy of measurements, or it could indicate a movement of a local micro-plate.

4.9.1.3. Geodynamic measurements in Slovenia

Although Slovenia is a small country, it lies in a tectonically very interesting area. Its territory is the meeting-point of three different geological units: Alpine, Dinaric and Pannonian. The larger part of Slovene territory, i.e. the northern and north-western parts of the country, belongs to the Alpine region. The smaller, southern part of Slovenia with the Karst, belongs to the Dinaric region, and the Pannonian massif is limited to the eastern part – the Prekmurje region.

The Alpine and Dinaric regions formed part of the European fold mountains created in the Tertiary period. The Pannonian massif is, by its origin, much older and, being a stable and resistant mass, influenced the development of the Alpides. Under its influence the Alps were split into two branches – the Carpathian and the Dinaric Mountains. The consequence of this split were numerous faults with very interesting geological processes. For the territory of Slovenia, the most interesting are the Dinaric and transverse-Dinaric faults and north-south faults on the northern periphery of the Adriatic. The situation is more complex because of the Adriatic plate that is the source of numerous movements and earthquakes.

Slovenia is a country that has experienced relatively strong earthquakes. For this reason seismological research has a rich tradition. Following the earthquake in 1895, Ljubljana received the first seismological station in the south-eastern Europe. For the first geodetic measurements of neotectonic movements we had to wait very long – until the technological development of electronic distance meter made possible precise distance measurements.

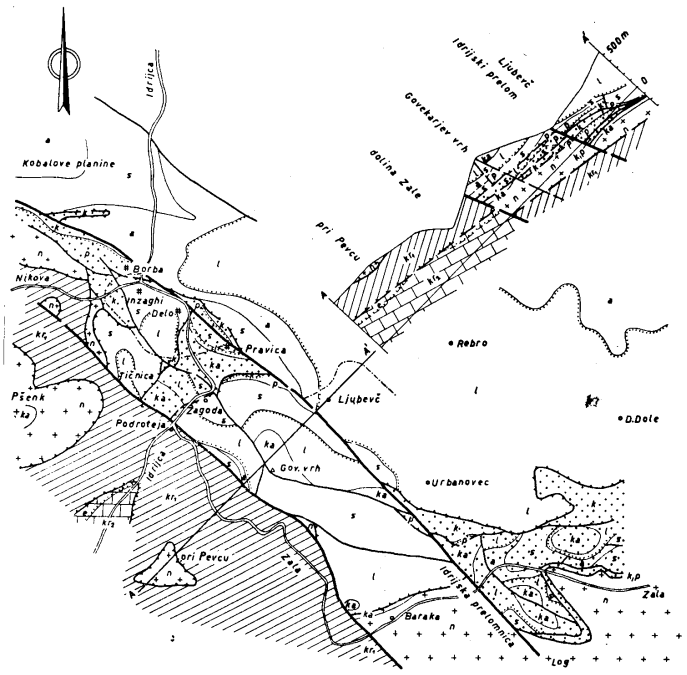

Fig. 4.9.1.4. Geological structure in Idria region

As the first geodetic measurements of tectonic movements are considered the measurements made by Prof. R. Vodušek with the distance meter AGA 6 on the mercury mine in Idria region. Geologists have found and located the movements of a part of mercury ore deposit in geological history. The sizes of these movements were 2500 m in horizontal direction and 400 m in vertical direction (Fig. 4.9.1.4.). Prof. Vodušek has made some measurements at the end of seventies and has found movements in the interval of some centimetres. The price-cut of mercury has stopped these measurements, so the picture of neotectonic movement situation in that region has remained undetermined till now.

In 1976, the Geodetski zavod Ljubljana (GZ) began to participate in such a research for the first time by performing geodetic measurements. Following the study of shifts in the region of the Karavanken Mountains in co-operation with Austria (TU Vienna), new investigations based on geodetic measurements followed in other parts of Slovenia. The more recent GPS networks joined standard terrestrial networks.

- ## Tectonic movements along the Idria fault

The tectonic movement along the Idria fault has already been mentioned above. The displacement amounts to 2500 m. It is significant that researches (Dr.Placer) indicate these movements primarily as a counter-clockwise rotation. And this means not only the movement of the Adriatic plate northwards is present, but also the rotation of a part of the Adriatic plate, the Istrian micro-plate, comprising the entire Istria (the Istrian peninsula with the hinterland up to Idria). So there is a new micro-plate as a part of the eastern Adriatic plate. The centre of rotation is located somewhere in the middle of the Adriatic Sea. The relief of Istria indicates that not only is Istria rotating, but also tilting, because there is the western jagged coast and the eastern smooth coast.

- ## Measurements in Karavanken Mountains

Slovenia – Geodetski zavod, and Austria TU Vienna have started as early as in 1977 with the first measurements of the neotectonic movements in Karavanken Mountains. Precise enough measurements were made possible by the appearance of electronic distance meters. Separately have been measured the Slovene and Austrian part of the geodetic network. Three measurements have been carried out so far. Let us have a look at the Slovene part of the network.

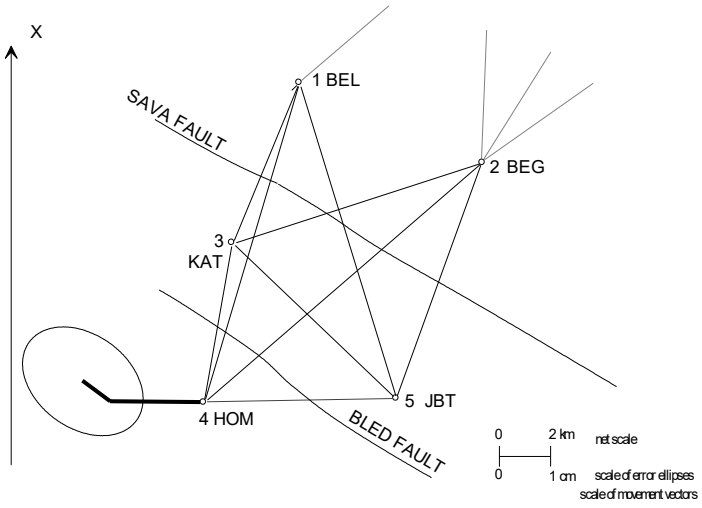

Fig. 4.9.1.5. Movements of points of the Karavanken Mountains network

In Fig. 4.9.1.5. can be seen that the displacement of the point 4 is approximately 20 *mm*. In like manner as in Idria, this displacement was counter-clockwise, too. The displacement amounts to 1 *mm* per year. In million years that would result in the displacement having been determined in Idria. This is an additional affirmation of the Idria micro-plate existence.

4.9.1.4. Results of the CERGOP network adjustment

The CERGOP is certainly one of the most successful GPS campaigns in Central Europe. The network has been adjusted several times. Let us have a look at the results of one of these adjustments.

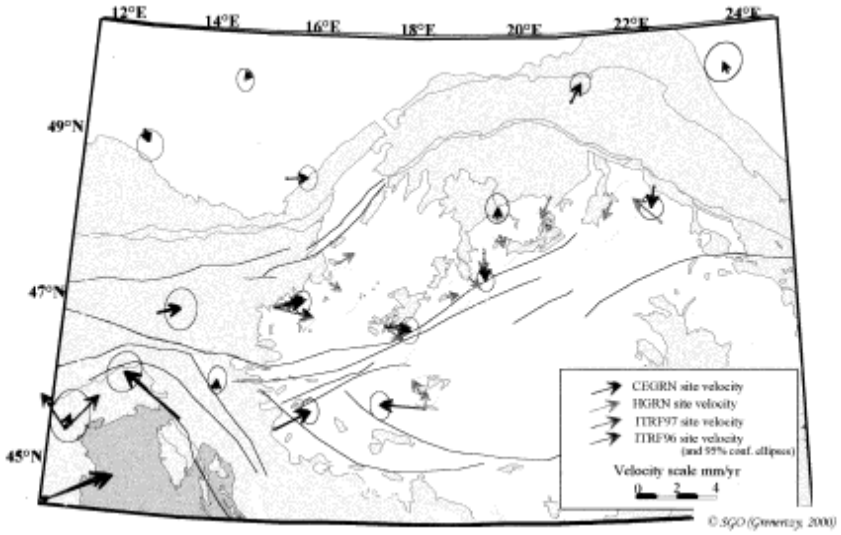

Fig. 4.9.1.6. Displacements defined by adjustment the CERGOP network (Grenerczy)

In Fig. 4.9.1.6. are shown neotectonic movements defined by Mr. Grenerczy in his doctoral dissertation. We are only interested, indeed, in the Adriatic plate. A displacement of a point at the north-west of Istria – Malija, also indicates the counter-clockwise rotary motion of the Istria micro-plate. This result demonstrates again the existence of the Istria micro-plate as a part of the Adriatic plate.

4.9.1.5. Conclusion

The modern measuring methods make it possible to detect neotectonic displacements in a very short time. Such detections are not intended only for themselves, they are used in defining the edges of tectonic plates that are usually focal points of earthquakes. When displacements along the faults are known, the area of predictable earthquakes can be defined. The results of researches at the Adriatic plate are very interesting. The Adriatic plate between the European and African ones is relatively small and broken into many smaller plates. This means a lot of faults, and consequently focal points of earthquakes. The results of previous researches in following up the earthquakes in that area are to a high degree in accordance with the results of measurements of the neotectonic displacements.

The importance of that area (northern Italy: industry; Slovenia: transport; Croatia: tourism) is so high that the follow-up of the appropriate measurements in that area is necessary. All the so far existing measurements have to be combined into a single project that should allow a uniform synthesis of the results of international projects.

4.9.1.6. References

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