THE USE OF ELASTIC REBOUND MODEL IN DESIGN AND EVALUATION OF DEFORMATION

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ABSTRACT

This research emphasizes on the usefulness of Reid's theory in the early detection of crustal deformation even when the random errors are not statistically significant.

INTRODUCTION

It was not until 50 years after Alfred Wegener introduced his plate tectonics hypothesis (1910),that it became world wide accepted. This hypothesis stated that the earth's lithosphere is composed of rigid plates that are in relative motion along their boundaries, over underlying asthenosphere. Accordingly, Bock (1983) assumed that earth's surface has relative secular motions of 1-10 cm per year, depending on which plate is concerned. Furthermore, Reid, after detailed analysis of the relative crustal movements along the San Andreas fault associated with the 1906 San Francisco earthquake, set up "the elastic rebound model";a theoretical model for the strike-slip faulting process(Benioff,1964).Since then, the implications of this theory has stood as an invaluable predictor of crustal deformation, particularly when geodetical models are applied (El-Ghazouly, 1988 a).

Analysis of the deformations obtained by combining different estimation models and the geophysical model, revealed that similarity of the magnitude of the noise to that of the geophysical model could prejudice the predictability value of the procedure. Furthermore, El-Ghazouly (1988 b) failed to predict actually existing movements when he applied the Bayesian model in his study. Many procedures have been postulated to obviate this error as is a combination of baseline measurements and geophysical models (Bock, 1983). This misinterpretation can also be avoided by using Reid's model in the adjustment, a procedure used in this study.

MATERIAL AND METHODS

The free network model has been used in this study to avoid the above mentioned problem. The observational noise is minimized in the observation space and the datum transfer between two epoch is performed through the minimization of the coordinate changes in the solution space.

A group of stations has been minimized in order to define geometrically, in free adjustment, the translation, rotation and scale defect in the geodetic networks. This group, being unchanged in shape and size in both epochs in question (epoch A and epoch B in this study), has been elected according to the statistical hypothesis H_o:

The steps of the adopted approach are shown in Figure (1). The blunders are first detected by the Danish method, a minimum of coordinates is then fixed and the tau (τ) statistical test is used to detect the outlier. The datum is next transferred according to the Ho: hypothesis, tested by the congruence analysis program which includes graphic and numerical tests.

The non quantitative models, eventually obtained, revealed the deformation process that confirms the suitability of the statistical hypothesis H_o: for the free adjustment network even if the measurement errors (noise) and the expected deformations are similar.

THE ELASTIC REBOUND MODEL

Reid analyzed the relative horizontal crustal moments along the San Andreas fault associated with the 1906 San Francisco earthquake (Benioff, 1964).

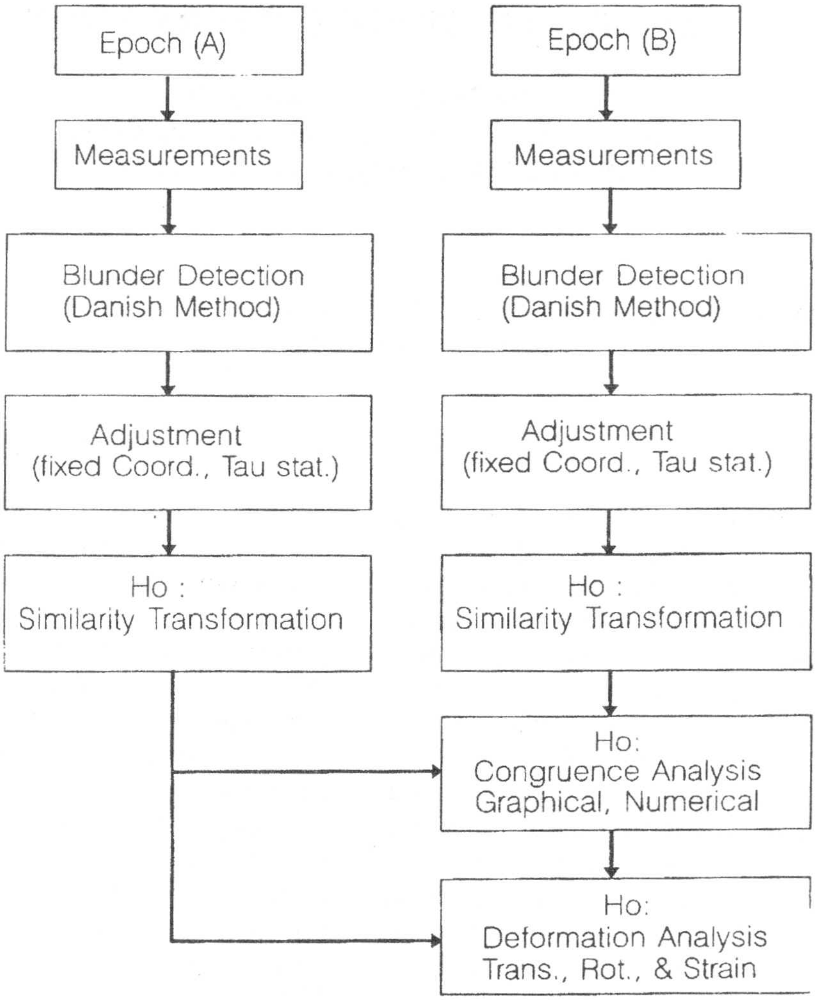


Figure 1. Flow chart used in the analysis.

In order to interpret the data from repeatedly observed geodetic networks, he set up the elastic rebound model, a theoretical model for the strike-slip faulting process which proved to be an effective addition to the free network approach. El-Ghazouly (1988 b) demonstrated that modern plate tectonics distinguishes four principal modes of interaction between lithospheric plates as in Figure (2) as follows:

a- Subduction boundaries,
b- Transcurrent, or Strike-slip, plate Boundaries,
c- Extrusion zones or spreading centers, and
d- Accretion zones and zones of orogenic collision.

The strike-slip, or transcurrent faults Figure (3) are designated as right or left lateral, depending on the sense of relative displacement. The time sequence of the model is depicted in Figure (4), along a right lateral strike-slip. According to Reid's theory the unstrained condition along a fault at epoch t_o is represented by regular grid and line a-a' is drown (epoch t_o). A large amount of strain is accumulated at epoch t_1 and line a-a' is deformed to a curved line with the maximum flexure at the fault. Another straight line b-b' is drawn in epoch t_1 . If at some time and some point or zone along a fault the accumulated strain exceeds the frictional strength holding the two blocks together, then a very rapid crustal motion occurs creating an earthquake (during the earthquake most of the stress is released and the accumulation of strain starts again). After the earthquake at epoch t_2 there is an unstrained condition again with the offset and curved features of a-a' and b-b'.

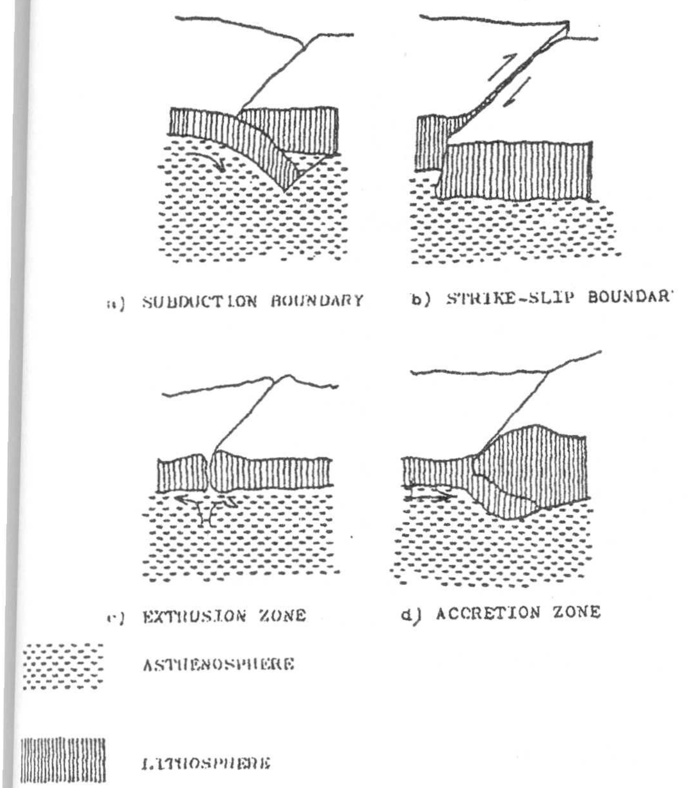


Figure 2. Interaction between tectonic plates (Schneider, 1982).

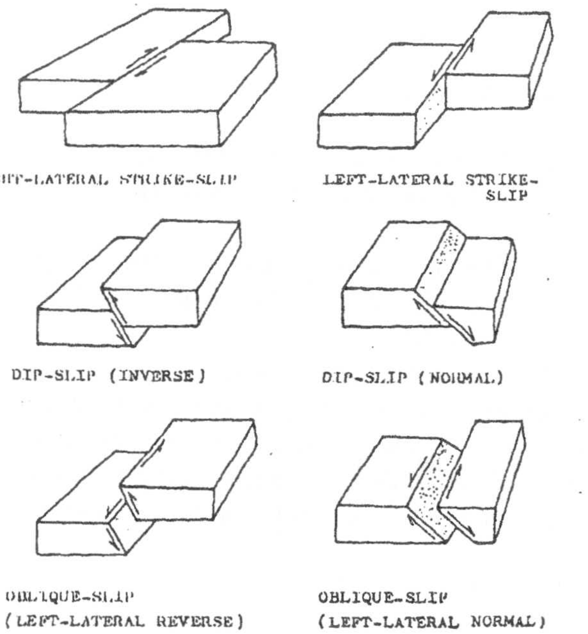


Figure 3. Strike-slip, dip-slip, and oblique-slip faults (Berline, 1980).

The duration of the slip is estimated to be a fraction of second and up to 10 seconds. The expanded Reid's concept including various aspects of frictional sliding describe a various stages of deformation as follows:

a- Secular, which is slow but continuous movements.
b- Pre-earthquake, more rapid movements (years to hours).
c- Earthquake, very sudden movement (seismic slip), and d-Post-earthquake, rapid movement (weeks to months)

Stages (b) and (d) do not always accompany stage (c).

GEODETIC OUTCOME OF THE THEORY

The elastic rebound model which describe the deformation process at the vicinity of the active fault can help in design and evaluation of the deformation survey. From Figure (4) the general rules of the network design can be stated as follows:

Firstly; Because the two blocks have similar behavior it is suitable to set the points of control stations into zones symmetric to the faults after the strain relief condition. The internal zones show the deformation characterizing the process along the fault.

Secondly; If an investigation of the strain distribution is required the wing and internal zones have to be filled by additional ones, (Savage, 1978 shows in the simplest model the plate boundary which is thought of as a zone several hundred kilometers wide that accommodates relative plate motion continuously distributed deformation as in Figure (5)).

For the evaluation of the deformation survey by free adjustment solution and step-wise analysis, between the two epoch (A) and (B),the statistical hypotheses H_o are investigated. Reference is made to Figure (4), from which:

Case I of H_o:

(a) At epoch (A) the measurements were carried out under the unstrained condition (a-a' is a line at epoch t_o)

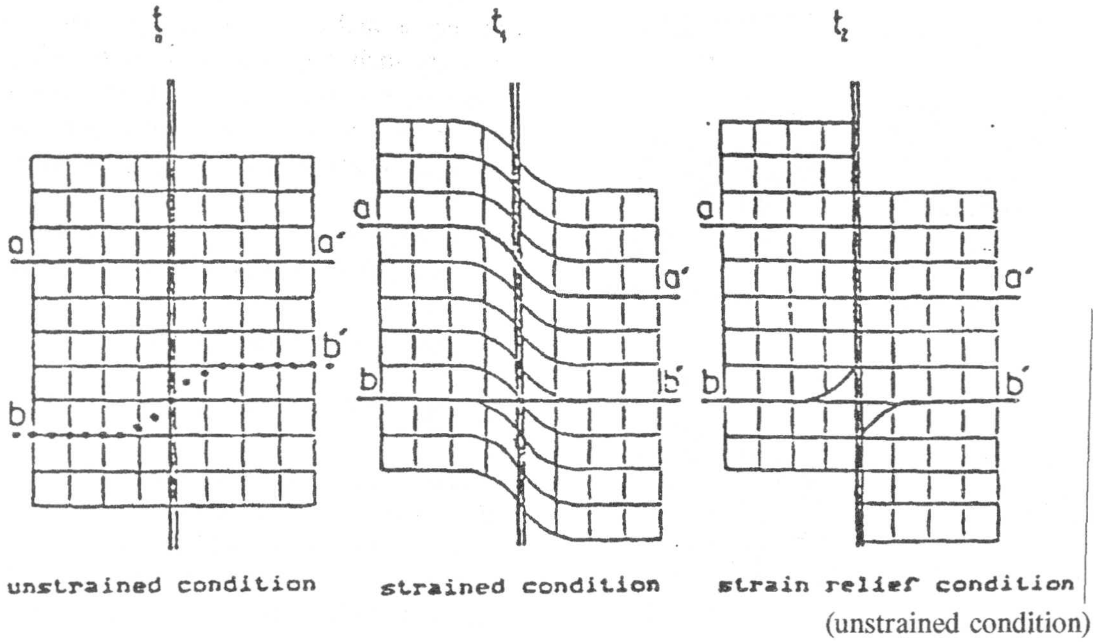


Figure 4. The Time sequence of the Reid's theory.

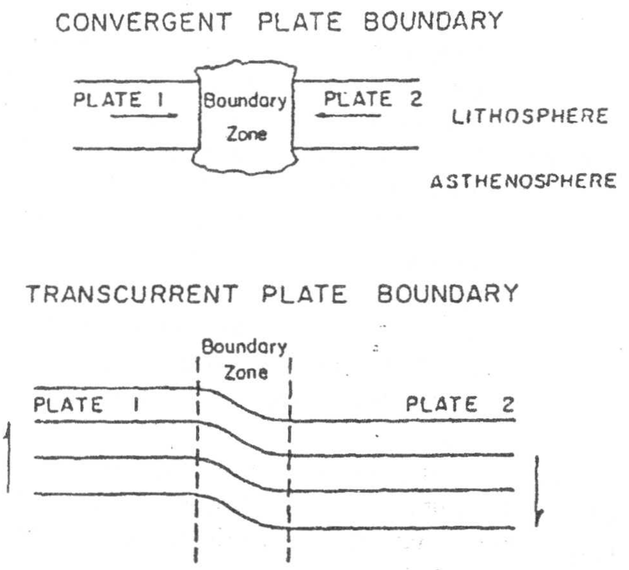


Figure 5. Plastic boundary zone at the plate margin. The upper Figure shows a vertical section across a convergent boundary, and the lower figure shows a plan view of a transcurrent boundary.

(b) At epoch (B) the measurements were carried out under the strained condition (a-a' is a line at epoch t_1).

Case II of H_o:

(a) as in case I .
(b) The measurements at epoch (B) were carried out after the strain relief condition (a-a' is a line at epoch t_2).

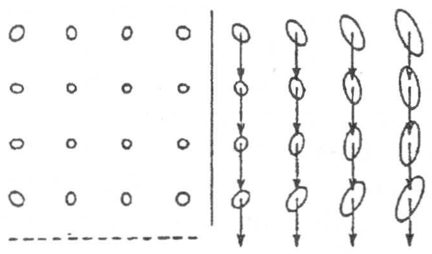
Case III of H_o:

(a) At epoch (A) the measurements were carried out under the strained condition (b-b' line at epoch t_1).
(b) The measurements at epoch (B) were carried out after the strain relief condition (b-b' line at epoch t_2).

In different hypotheses case I, case II and case III the different zones of control stations have to be the subject of the minimization in free adjustment solution which is basically a relative approach. Confidence intervals also depend on this choice (datum transfer).

For Case I H_o:I

any side of the fault may be an acceptable choice as shown in Figure (6).



------ zone of minimalization

Figure 6. First solution for (H_o:I).

In Case II: H_o:II

any wing zone or fault zone may be an acceptable choice which appear in Figure (7).

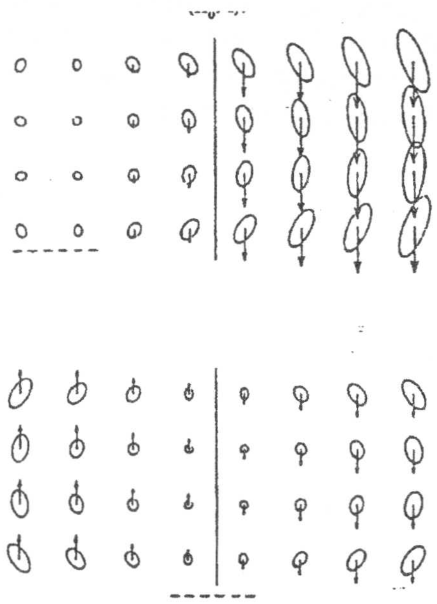


Figure 7. Second solution for (H_o:II).

The last Case H_o:III

Any wing zone or both together may be an acceptable choice as depicted in Figure (8). The last statistic is the strongest one.

The hypotheses which mentioned before may be accepted or rejected according to the applied congruence tests. A single point movements can be filtered and the proposed concept maybe changed according to the available data and special circumstances.

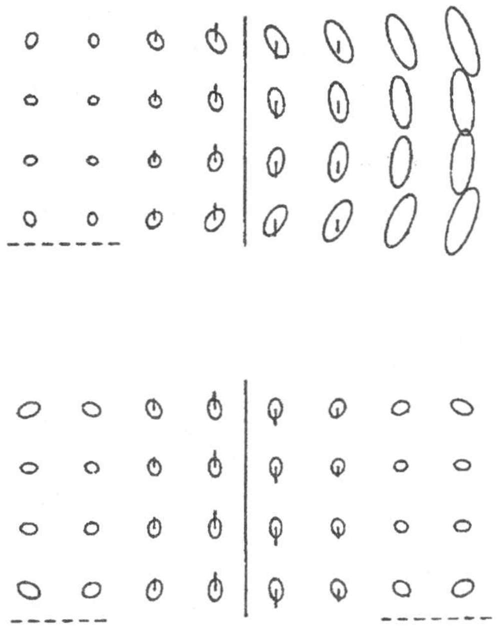


Figure 8. Third solution for (H_o: III).

CONCLUSIONS

The use of Reid's elastic rebound model as a comprehensive description of deformation along an active fault is concluded from the surveys where the detected displacement were more significant than the observation noise. The geodetic consequences can be applied in free network approach as stated above when the noise level is near to the expected deformations, which makes possible the early recognition of the process even if they are not significant from statistical point of view. This model can be applied on areas like that around Aswan dam to predict any movements that might endanger the body of the dam..

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