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A seismotectonic investigation in the Geneva Basin, southern Jura Mountains

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ZUSAMMENFASSUNG

Im Gebiet des Genfer Beckens wurde von April 1983 bis März 1984 mit Hilfe eines Netzes von vier mobilen Erdbebenstationen (Typ SER-2 des Instituts für Geophysik der ETH Zürich) eine Mikroerdbebenuntersuchung durchgeführt. Die Aufzeichnungen lassen für diesen Zeitraum eine unregelmässige Seismizität erkennen. Am 16. November 1983 erfolgten kurz nacheinander zwei Erdbeben (Magnitude M_L 2,3 und 2,6) mit identischen Seismogrammen, deren Epizentren in der Nähe des Vuache-Bruches lagen.

Der Herdmechanismus dieser Beben ist vom Horizontalverschiebungs-Typus. Die P-Achse ist N 120° E orientiert. Die Knotenebene mit sinistralem Verschiebungssinn zeigt dasselbe Streichen wie der Vuache-Bruch. Eine Analyse der jüngsten, lokalen Deformation ergibt ebenfalls eine N 120° E orientierte maximale horizontale Krustenverkürzung. Das tektonische Spannungsfeld, welches die heutige Seismizität im Gebiet des Vuache erzeugt, ist in seiner Orientierung sehr ähnlich dem Spannungsfeld, welches die pliozäne Deformation verursachte. Die Vuache-Bruchzone ist eine seismoaktive Bruchzone.

RÉSUMÉ

Une étude séismotectonique dans la région du bassin genevois a été effectuée entre avril 1983 et mars 1984. Quatre stations de type SER-2 (Event Recorder à 3 composants de l'Institut de Géophysique, ETH Zurich) étaient installées et ont été opérationelles pendant cette période. Les résultats ont démontré one activité sismique irrégulière. Deux séismes, survenus le 16 novembre 1983 et localisés près de la faille du Vuache ont présentés des caractéristiques identiques.

Le méchanisme au foyer résultant d'une «composite solution» a pu être défini d'une manière précise avec une orientation de l'axe P, N 120° E. Il pourrait suggérer un mouvement sénestre de la faille du Vuache. La direction de la compression maximale a pu également être observée dans des déformations locales (N 120° E). Il s'agit apparemment d'un processus tectonique qui se poursuit encore à l'époque actuelle.

ABSTRACT

A seismotectonic investigation was carried out in the area of the Geneva Basin. Four mobile SER-2 Stations (3 Component Event Recorders of the Institute of Geophysics, ETH Zurich) were installed and in operation between April 1983 and March 1984. During the survey, 27 local, small events could be recorded. On 16 November 1983, two earthquakes of M_L 2.3 and 2.6, showing identical characteristics, occurred successively near the Vuachefault. The focal mechanism (composite solution) for these two earthquakes is of the strike-slip type with the P-axis oriented N 120° E and suggests a sinistral movement along the Vuache fault. The same orientation of the maximum compression (N 120° E) was also observed in local deformation. This similarity confirms a tectonic process which is apparently still going on.

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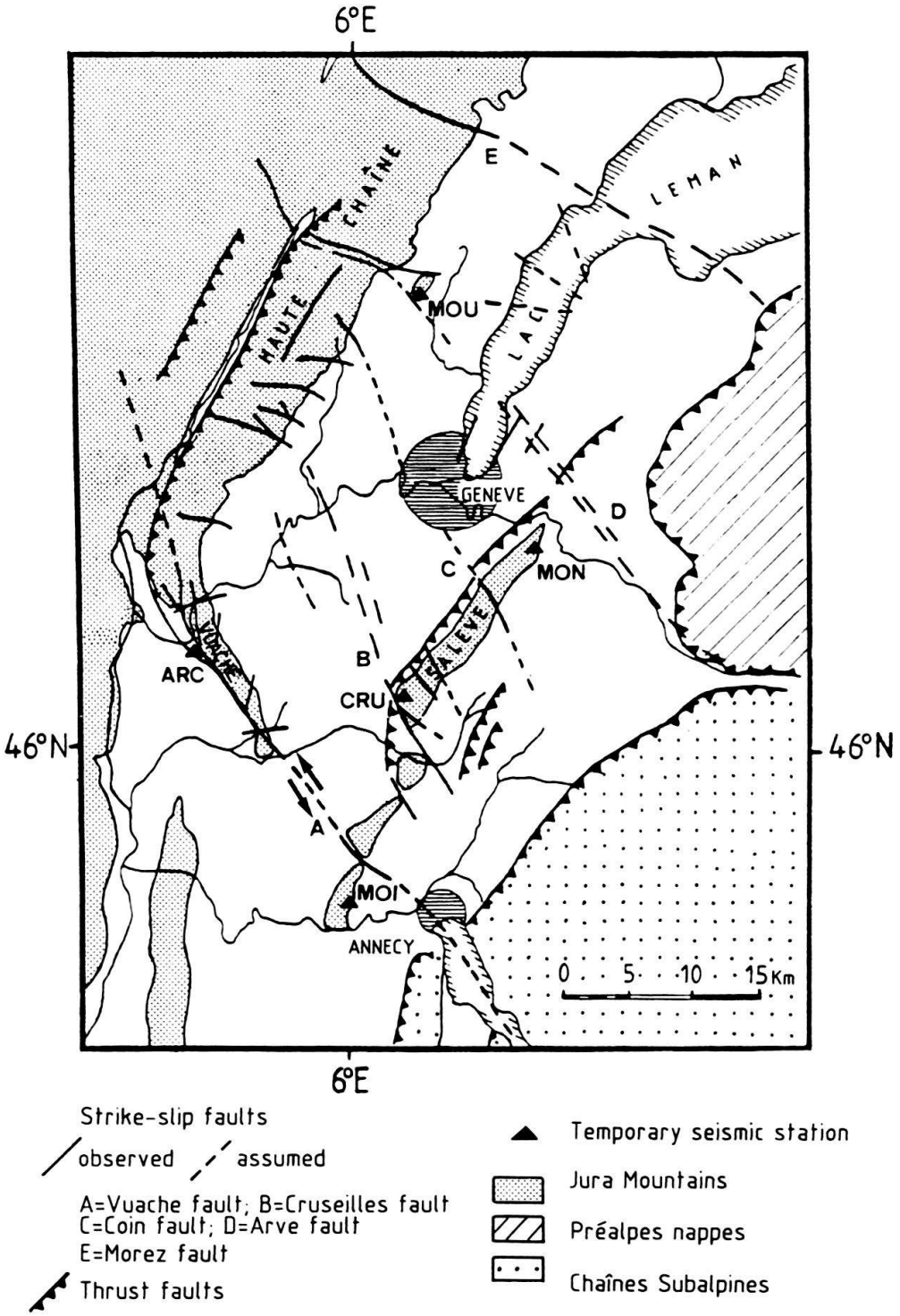

Fig. 1. Tectonic map of the Geneva Basin. (Fault system after AMBERGER & RUCHAT 1977.)

Geology and tectonics

The Jura Mountains are a young arcuate chain of fold-thrust mountains mainly of Pliocene and late-Miocene age. The Mesozoic cover has been detached from its substratum (décollement), along incompetent members of Triassic-age formations. The amount of horizontal displacement of the sedimentary cover movement with respect to the basement varies from 2 to 25 km. In the southern part, the chain consists of a series of major folds (faisceau helvétique) trending SSW–NNE. Near Bellegarde, the trend changes to SSE. The Vuache Mountain is linked with a left-lateral strike-slip fault, the Vuache fault, which crosses the Molasse Basin. Near Annecy, this structure joins up with the most westerly folds of the French Chaînes Subalpines, which were folded at the same time as the Jura Mountains.

The Geneva Basin is bounded by important geological structures (Fig. 1). The highest anticline of the Jura (Haute Chaîne) forms the boundary to the north and northwest, the monocline of the Vuache to the southwest, the Salève Chain which also belongs to the Jura Mountains to the southeast and finally, the Arve fault to the northeast. Between these structures lies the Molasse Basin, which essentially consists of Tertiary fluviatile and shallow marine sediments, covered by Quaternary deposits.

Seismicity

The Geneva Basin region shows local seismic activity. From the 13th century until 1982, approximately one hundred earthquakes with epicentral intensities greater than VI MSK were reported (AMATO 1983). The present micro-earthquake study was performed because it was noted that several of the historic events were located near the Vuache fault.

Four mobile seismic stations (3 component event recorders Type SER-2 of the Institute of Geophysics, ETH Zurich) were installed and in operation between April 1983 and March 1984 (Table 1). This study was performed within the scope of a diploma thesis at the Federal Institute of Technology Zurich (SAMBETH 1984).

During this period, while the network was in operation, an irregular seismic activity was observed. 27 local earthquakes ranging from 1 to 2.6 in magnitude M_L were recorded. Two of them with magnitudes M_L 2.3 and 2.6 were located at the Vuache fault. These two earthquakes of 16 November 1983 show identical seismograms for all three components. This interesting observation allows to establish an accurate composite solution for the focal mechanism. A more recent earthquake occurred on 3 May 1984 in the region of the Arve transcurrent fault near Cluses (France). The magnitude

Table 1

Station	Latitude	Longitude	Altitude
ARC	46 N 5.15	5 E 54.08	550 m
CRU	46 N 3.75	6 E 6.54	1000 m
MOI	45 N 54.83	6 E 2.44	580 m
MON	46 N 9.43	6 E 13.26	670 m
MOU	46 N 20.22	6 E 5.95	700 m

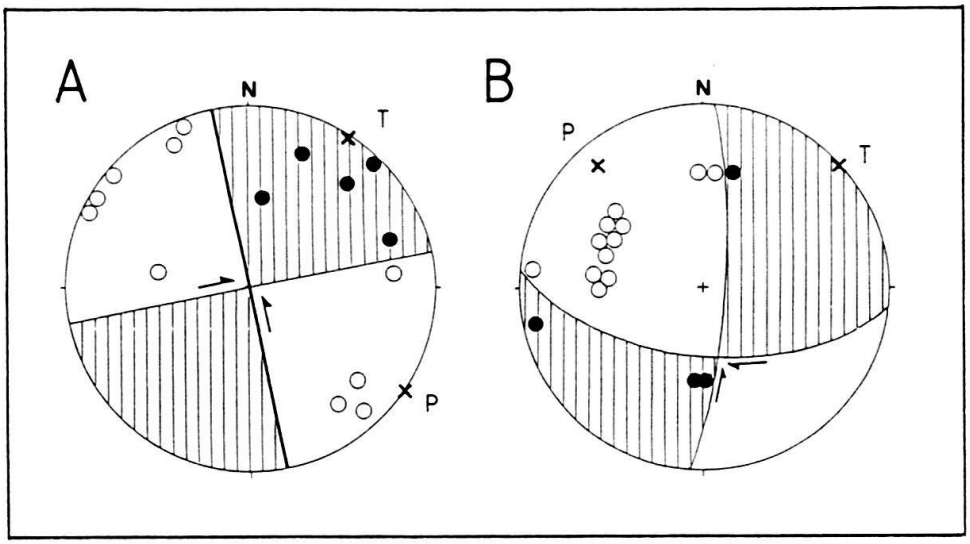

Fig. 2. A: Composite fault-plane solution based on the two earthquakes of 16 November 1983. P-axis (trend/plunge) 124/0. T-axis 34/0. B: Fault plane solution for the earthquake of 8 November 1982. P-axis (trend/plunge) 320/13, T-axis 49/0. Lower hemisphere equal area projection. Dots: compression. Circles: dilatation. Hatched: compressional quadrants.

M_L was 3.5 and the focal depth 15 km, i.e. the earthquake originated deep in the crystalline basement.

Focal mechanisms of 16 November 1983 and 8 November 1982 earthquakes

The focal mechanisms of the two Vuache earthquakes of 16 November 1983 as well as the one of the Bonneville earthquake of 8 November 1982 were investigated in detail (Fig. 2). The mechanisms of the Vuache earthquakes are well determined and are of the strike-slip type. The orientation of one of the nodal planes as well as its sense of displacement fit remarkably well with the type and orientation of the Vuache fault. For this reason, it is assumed that the earthquake generating movement occurred along the N 179° E trending fault plane with sinistral lateral displacement. The mechanism of the Bonneville earthquake indicates predominantly lateral slip displacement. There is no geological evidence to decide along which of the two planes the actual movement took place. The orientation of maximum horizontal pressure, as determined by the focal mechanism, is N 124° E for the Vuache and NW–SE for the Bonneville earthquake.

During the last few years, a number of fault-plane solutions of earthquakes in the Geneva area were investigated by different authors. These solutions are represented on the seismotectonic map (Fig. 5) and in Table 2.

The two events of 16 November 1983 occurred within a time span of 25 minutes, showing identical seismograms. Evidently they represent a repeated movement of the same type on the same fault plane within this short time. The velocity–depth model adapted to the area was established on the basis of refraction-seismic data, borehole data and with the help of modelling, using the earthquakes as sources. The finally chosen three-layer crustal model best fits all the available data and allows optimal localization and depth determination (SAMBETH 1984). The focal depths were further

Table 2: *Focal mechanisms of earthquakes of the Geneva region.*

Date (GMT)	Time h m s	Lat. N Deg.	Long. E Deg.	Mag ML	P-Axis Az/Incl	T-Axis Az/Incl	Reference
05.02.1968	02:28:49	46.6	5.8	3.5	134/07	314/83	Pavoni & Peterschmitt (1974)
21.06.1971	07:25:29	46.4	5.8	4.4	315/32	54/14	Pavoni & Peterschmitt (1974)
09.06.1974	00:18:09	45.98	6.35	3.6	276/00	6/00	Fréchet (1978)
08.01.1975	09:12:45	46.80	5.78	3.7	146/24	238/04	Dorel et al. (1983)
29.05.1975	00:32:39	46.04	6.02	4.2	106/06	199/23	Fréchet (1978)
27.07.1976	17:51:56	45.90	6.70	3.1	265/00	355/00	Fréchet (1978)
02.12.1980	05:58:14	45.83	6.28	4.3	258/13	167/07	Thouvenot (1981)
08.11.1982	13:02:33	46.15	6.27	3.8	320/13	49/00	Sambeth (1984)
16.11.1983	00:02:42	46.02	5.98	2.3	124/00	34/00	Sambeth (1984)
16.11.1983	00:27:58	46.03	5.96	2.6	124/00	34/00	Sambeth (1984)

confirmed by a macroseismic analysis using a method developed by SPONHEUER (1960). By application of the Hypoellipse earthquake location program (LAHR 1976), the epicenters of the two events could be well localized near the Vuache tear fault on the southeastern end of the Vuache mountain. The focal depths vary between 3 and 5 km and indicate a localization within the transition zone between Mesozoic cover and crystalline basement.

Comparison of seismological and geological data

The purpose of this paper is to discuss the seismologically determined movements within the scope of young local tectonic deformations of the Vuache zone. A kinematic analysis of tectonic deformation observed in the quarry of Entremont, situated in the

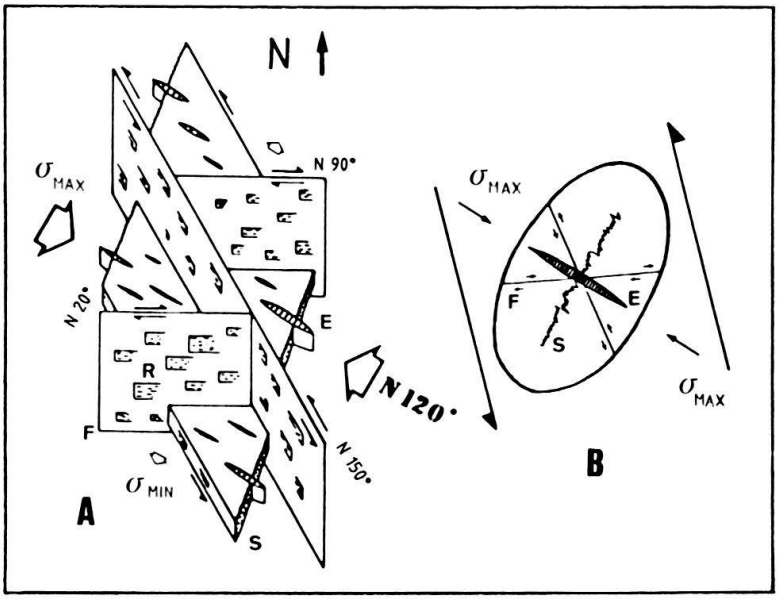

Fig. 3. Schematic representation of youngest, local deformations in the quarry of Entremont (A) and its possible explanation (B) (after BLONDEL 1984). This model shows observable deformations in a sinistral strike-slip faulting system.
E = extension split; F = strike-slip faulting; S = stylolithe plane; R = «Rutschharnische»; σ max., σ min.: principal stresses.

northwest of the Vuache Mountain, is shown in Figure 3. The style of deformation is similar throughout the Vuache Mountain. A comparison of seismological (Fig. 4) and structural data (Fig. 5) reveals a close relationship between the present tectonic movements and late-Alpine faulting. The present stress field causing the seismic activity of the Vuache tear fault appears to be very similar in its orientation (N 120° E) to the stress field of the Pliocene deformation. This orientation may be compared with orientations of P- and T-axes of focal mechanisms for the Geneva region represented in Figure 5.

A rotation of the maximum horizontal principal stress from NNW–SSE in the north of the Jura Mountains to E–W in the south of Geneva is clearly indicated by the orientation of the P-axes. This rotation is subparallel to the orientation of maximum horizontal shortening derived from a kinematic analysis of the Pliocene fold structures of the Jura Mountains and the Chaînes Subalpines (Pavoni 1975, 1980).

Discussion

The present arcuate structure of the Jura Mountains has been shaped by the folding during the main, late-Miocene to early-Pliocene compression phase; however, this folding probably began even earlier (Eocene). Sediments of that period were found in various faulted zones in the area of the Geneva Basin.

Observations lead to the conclusion that preexistant faults cross this basin. The grid of these old faults might have strongly influenced the folding of the Jura Chain. The focal depths suggest movements in the basement and in the sedimentary cover. The basement faults probably cause and guide the deformations of the sediments. The detailed investigations of the seismic activity in the Vuache area prove that the present tectonic movements are in close relation to the movements of the main folding phase.

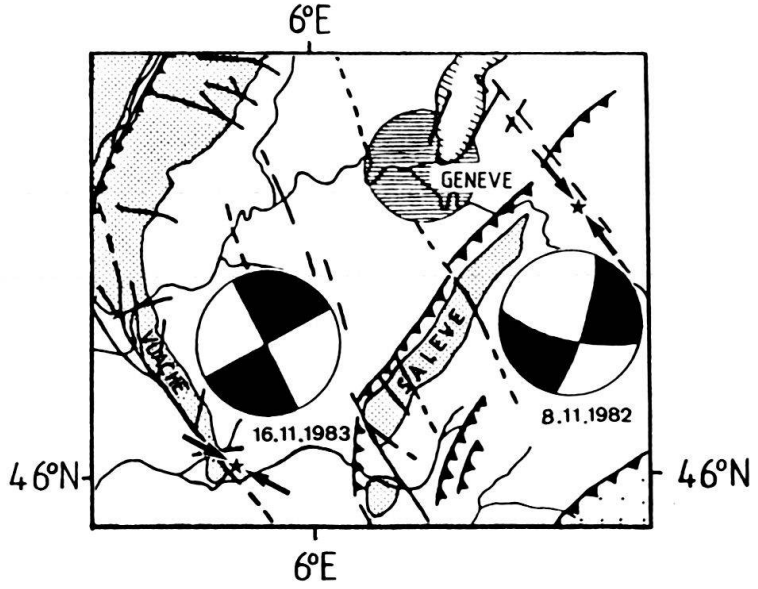

Fig. 4. Tectonic map of the Geneva basin with the two fault-plane solutions for the earthquakes of 8 November 1982 and 16 November 1983 (lower hemisphere). Arrow couples: orientation of the P-axis. Black: compressional quadrants. Star: epicenter. Tectonics: same legend as for figure 1.

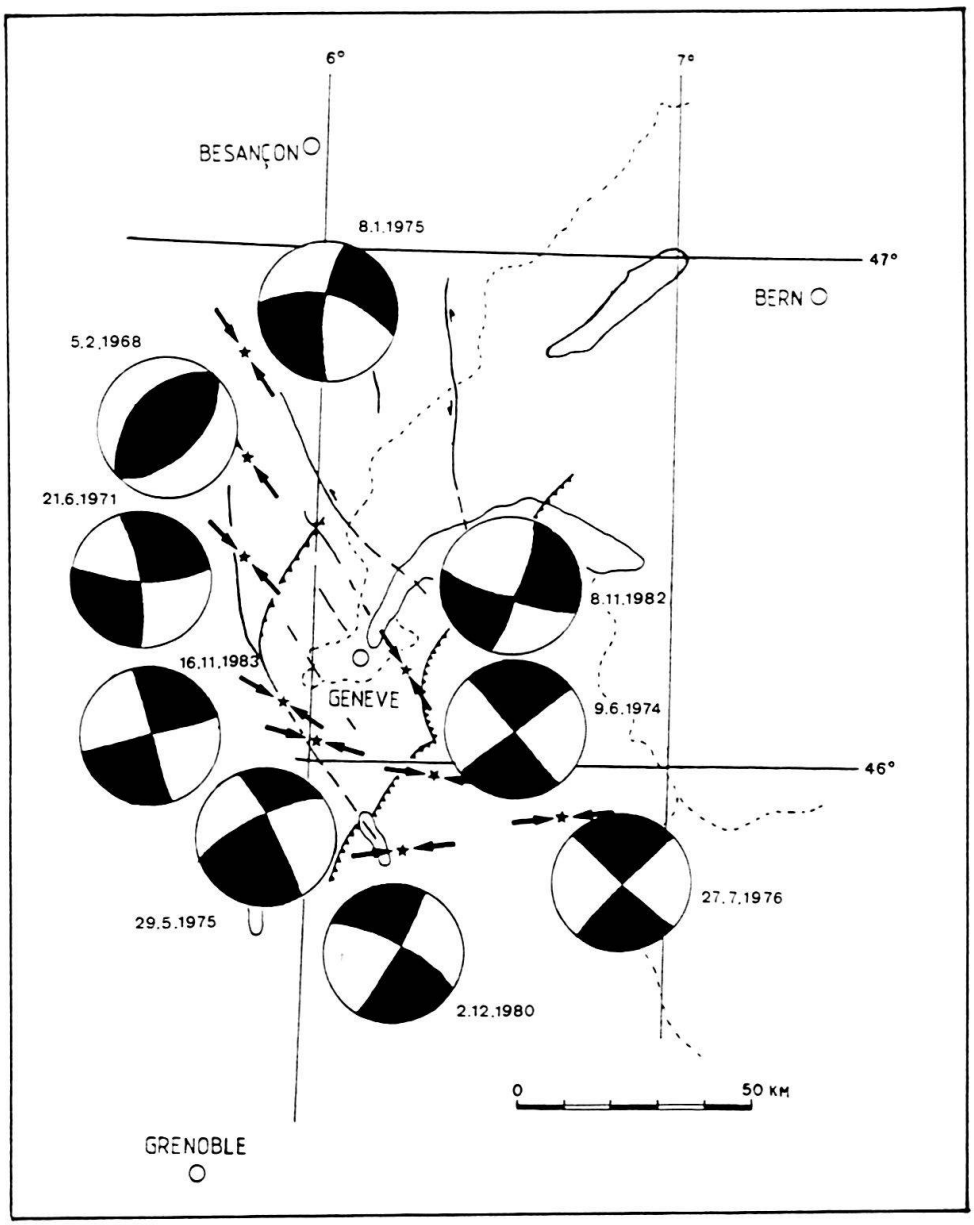

Fig. 5. Focal mechanisms synthesis in the region of the Geneva basin.

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REFERENCES

AMATO, E. (1983): Etude de la séismicité historique de la faille du Vuache. – Dipl. Univ. Genève (inédit).

AMBERGER, G., & RUCHAT, C. (1977): Etude de la fracturation tectonique active dans le canton de Genève et ses environs. – Rapp. Serv. Cantonal de Géol. Genève.

BLONDEL, T. (1984): Etude tectonique de la partie septentrionale de la montagne du Vuache (Haute-Savoie, France). – Dipl. (2e partie) Univ. Genève (inédit).

DOREL, J., FRÉCHET, J., GAGNEPAIN-BEYNEIX, J., HASLER, H., LACHAIZE, M., MADARIAGA, R., MODIANO, T., PASCAL, G., PERRIER, G., PHILIP, H., ROULAND, D., & WITTLINGER, G.G. (1983): Focal mechanisms in metropolitan France and lesser Antilles. – Ann. Geophys. *1*/4–5, 299–306.

FRÉCHET, J. (1978): Sismicité du Sud-Est de la France et une nouvelle méthode de zonage sismique. – Thèse 3e Cycle Univ. Sci. Méd. Grenoble.

LAHR, J.C. (1976): Hypoellipse. A Computer Program for Determining Earthquake Hypocentral Parameters, Magnitude and First Motion Pattern. – U.S. geol. Surv., Open file rep., 80–59.

PAVONI, N. (1975): Zur Seismotektonik des Westalpenbogens. – Vermessung, Photogrammetrie, Kulturtechnik, Fachbl. *III/IV*, 185–187.

– (1980): Crustal stresses inferred from fault-plane solutions of earthquakes and neotectonic deformation in Switzerland. – Rock Mech., Suppl. 9, 63–68.

PAVONI, N., & PETERSCHMITT, E. (1974): Das Erdbeben von Jeurre vom 21. Juni 1971 und seine Beziehung zur Tektonik des Faltenjura. In: Approaches to Taphrogenesis. (p. 322–329). – Schweizerbart, Stuttgart.

SAMBETH, U. (1984): Seismotektonische Untersuchungen im Gebiet des Genfer Beckens. – Diplomarb. ETH Zürich.

SPONHEUER, W. (1960): Methoden zur Herdtiefenbestimmung in der Makroseismik. – Freiberger Forschh. *C88*, Berlin.

THOUVENOT, F. (1981): Modélisation bidimensionelle de la croûte terrestre en vitesse et atténuation des ondes sismiques. Implications géodynamiques pour les Alpes occidentales. – Thèse Univ. Sci. Méd. Grenoble. IRIGM.

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