한국측량학회지, 제 18 권 제 1 호, pp. 19~23(2000년 4월 25일)

The Estimation of Recent Crustal Movement along the Cam Lo fault from repeated GPS data
GPS 반복관측에 따른 캄로 단층의 최근 지각변동 평가

Vy Quoc Hai* · Lee, Young-Wook** · Kang, Joon-Mook***
Vy Quoc Hai* · 이용욱 · 강준묵

ABSTRACT

The estimation of crustal movements along the Cam Lo fault (Quang Tri province,Vietnam) from repeated GPS data (1995-1998) is addressed in this paper. The study area is relatively small and locates at about latitude of N 16 40' 10" and longitude of E 106 58' 40" in the middle of Vietnam. The network consists of 6 points, is located in 3 tectonics units, baselines are from 3 km to 11 km. GPS observationss were perforemed to the stations of our network during two campaigns in March 1995 and May 1998. Considering the relation of coordinate variation and its standard deviation based on the result, some remarks can be made: during interval from March,1995 to May,1998, there are movements in the investigated area, and the vertical movements are stronger than horizontal ones. The above results will be favor in a geophysical interpretation of Cam Lo fault for geologists. This seems to be an encouraging result in studying activity of faults in Vietnam.

要 旨

1990년 이래로, GPS 기술은 지각 움직임 연구에 적용되어 왔으며 본 논문은 반복된 GPS 관측으로부터 (1995-1998) Cam Lo 단층(Quang Tri province, Vietnam)의 지각 운동에 대한 연구 결과를 설명하였다. 연구대상지역은 위도 N 16 40' 10", 경도 E 106 58' 40"의 Vietnam 중앙부에 위치하며 그 규모는 상대적으로 작다. GPS 네트워크는 6개의 관측점들로 이루어져 있으며 기선거리는 3-11 km이고, 3개의 tectonic 지역에 위치한다. GPS 데이터 획득은 1995년 5월과 1998년 3월에 두 개의 캠패인으로 모든 관측점들에서 수행되어졌다. 연구결과, 좌표 변화와 표준편차를 고려할 때 대상지역이 움직이고 있었고, 수평 변화보다는 수직 변화가 더 크게 발생하였다. 본 논문의 결과는 지질 전문가에 Cam Lo 단층지역의 지구물리 해석에 흥미로운 자료를 제공할 것이고 베트남의 단층 활동 연구를 고무시킬 것으로 기대된다.

1. Introduction

Since 1990, GPS technology has been applied for study of crustal movements by Insititue of Geological Sciences (Hanoi, Vietnam) like other countries.[7-11] In regional scale we take part in Project GEODYSSEA (Geodynamics of South and South-East Asia), which is carried out by a large international group of participants, includes 22 agencies and institutions in 14 different Asian and European countries. The goal of this project is to study the overall plate motions in this region. For this purpose, the network of 42 stations was observed with GPS during two field campaigns in 1994 and 1996. The data were independently analysed by four groups using different software packages and analysis strategies. The individual network solutions resulted were combined by two campaigns averaged co-ordinate solutions. The precision of both co-ordinate solutions was found to be 4-7 mm for the horizontal, and 1 cm for the vertical component.[5)]

Besides regional projects, our Institute carry out study on some major fault, which play important role in recent crustal deformation in Vietnam. Geodetic measurements of Thac Ba network from 1963 to 1994 were processed in order to determine horizontal strain across the Red

*Post-doctor, Department of Civil Eng., Chungnam National University
**Doctor course, Department of Civil Eng., Chungnam National University
***Professor, Department of Civil Eng., Chungnam National University

River fault.[2] In neighbouring region seven stations of Tam Dao-Ba Vi GPS network were observed for estimation of movements of this fault in 1994 and 1996.[1]

Estimation of crustal movements along the Cam Lo fault (Quang Tri province) from repeated GPS data (1995-1998) is addressed in this paper. The study area is relatively small and located at latitude of 16 40' 10" N and longitude of 106 58' 40" E in the middle of Vietnam (Figure 1).

The Cam Lo fault,[4] extending about 170 km from Laos to Cua Viet (Vietnam), passes Vietnam-Laos frontier at Huoi nam se. In Vietnam, the fault is in curved shape: the first 38 km long section striking NW from Huoi nam se to Sơn Lam village (at 14 km W of Cam Lo), the second striking E from Son Lam village to Cam Lo is 13 km long and the last striking NE from Cam Lo to Cua Viet is 30 km long. 3/4 of fault in Vietnam run along the basin of Cam Lo river.

Result of different tectonophysical researches on various rocks aged Palaeozoic, Mesozoic and Cainozoic show that two main tectonic phases affected the Cam Lo fault's activity (section striking NE) in Neotectonics. In the early phase (Miocene), stress field is characterised by W-E compression and N-S extension, and compatible with normal, right-lateral slip along the Cam Lo fault. The later phase showed W-E extension and N-S compression stress state and normal, left-lateral slip tectonic feature

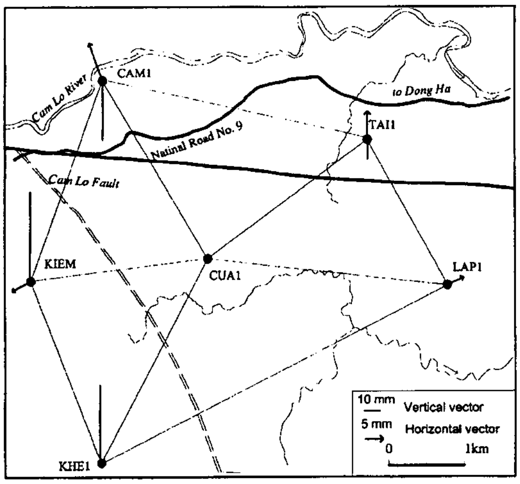

Figure 1. Sketch of quang tri network (along the Cam lo fault)

of the Cam Lo fault. Furthermore, other geological, geomorphologic and geophysical features of the Cam Lo fault also show left-lateral slip motion along it in the present day.

According to gravimetry data, the Cam Lo fault should release tectonic strain as earthquake with magnitude of up to 5.[4]

Strong surface crack on the S block (Cam Lo region) of the Cam Lo fault indicates the present day's activity of it.

2. GPS network establishment

Geodetic network was established at the beginning of 1995. There are two requirements for selecting benchmarks:

- at least two benchmarks to be on the same block of the fault
- the benchmarks to be built in bedrock excluding exogenous movements

The fulfilment of the two requirements is rather difficult because of the small study area. Thus, geologists have taken participation in the fieldwork in order to determine the border line between the plates, i.e. the fault locations, to find out the bedrock outcrops and to evaluate the stability of the outcrops for the benchmark building.

The benchmarks have built to fix a stainless steel marker in a drilled hole of diameter 10 mm and depth of 100 mm. The advantages of these benchmarks are: simplicity, fast, high stability, long life time and economy. However, there are some disadvantages: difficulty in finding the bedrock outcrop in a small area, and less

Figure 2. Observation station built in bedrock

precision of antenna position.

That is why we corrected carefully optical plummets before each campaign and every antenna setup has been done with precision of 1 mm.

Our network of six stations is located on 3 blocks of the Cam Lo fault (Figure 1). Figure 2 shows the distribution of six stations. The selected stations provide a good coverage of major tectonic blocks in the study area.

3. Observations

GPS observations were carried out at the stations of our network with two campaigns in March 1995 and May 1998.

The first campaign used four single frequency ASHTECH receivers. At least two independent sessions of 5 hours were observed on each station. Elevation mask was 15° and sync time (length of an epoch) was 15 seconds. Obtained precision is good for the relatively short baseline (3-11 km).

The second campaign used three dual-frequency Trimble 4000SSi receivers with sessions of 8 hours longer than in the former campaign. Elevation mask and sync time were as previously shown. The sessions were scheduled as follows:

1. session: CUA1-KHE1-LAP1
2. session: CUA1-LAP1-TAI1
3. session: CUA1-TAI1-CAM1
4. session: CUA1-CAM1-KIEM
5. session: CUA1-KIEM-KHE1

4. Data processing

Raw data were conversed into the RINEX format and processed using GPSurvey software, version 2.35. The strategy of baseline processing is summarized as follows:

- use of IGS precise ephemeris
- use of precise coordinates of fixed control station (CUA1)
- choose L1 fixed solution (1995 campaign) and Iono-free fixed (1998 campaign) for every baseline
- estimate zenith delay parameter every two hours

The best solution of baseline also depends also on several conditions such as the selection of suitable satellites, value of an elevation mask, epoch time based on estimation of loop closures.

Table 1 and Table 2 include the measured baselines and the values of loop closures of two campaigns respectively,

The ratio and the variance of fix solutions in 1995 measurement are relatively high. Besides the loop closures are approximately 1 ppm. It means that precise baselines are obtained in spite of single frequency data for this campaign.

At 1998 observation, Iono-free fixed solutions have considerably smaller variance and the loop closures are as before. The baselines are measured with high precision. This can be explained by dual frequency data.

To estimate relative movements between the blocks of the fault, we use adjustment fixing CUA1 station, which has precise coordinates and locates in the middle of network. The movements of other stations are compared relatively to this one. Results of adjustment are shown in Table 3. Obviously, the change of coordinates and their standard deviations can be computed from the adjusted coordinates and their standard deviations (Table 4).

Considering values of Table 4 we can have some results

Table 1. Baselines sobtained from both campaigns

(unit:m)

Baselines	1995(epoch)	1998(epoch)
KHE1-LAP1	11908.758	11908.758
TAI1-CAM1	7904.582	7904.586
CAM1-KIEM	5241.906	5241.924
CUA1-KHE1	6076.341	6076.338
CUA1-TAI1	5540.975	5540978
CUA1-CAM1	5043.440	5043.453
CUA1-KIEM	4778.667	4778.675
CUA1-LAP1	7746.688	7746.695
KIEM-KHE1	5368.180	5368.182
LAP1-TAI1	3400.113	3400.115

Table 2. Loop closure **(unit: ppm)**

N	Loop	Length (km)	1995 (ppm)	1998 (ppm)
1	KHE1-CUA1-LAP1	16	1.2505	0.3829
2	LAP1-CUA1-TAI1	26	0.7543	0.6498
3	TAI1-CUA1-CAM1	17	0.5939	0.2199
4	CAM1-CUA1-KIEM	18	1.3498	1.3679
5	KIEM-CUA1-KHE1	15	0.5462	1.3867

Table 3. Adjusted coordinates and their standard deviation

Station		1995			1998		
		Latitude(second)	Longitute(second)	Height(m)	Latitude(second)	Longitute(second)	Height(m)
CAM		21.418478	52.438706	4.817	21.418835	52.438594	4.785
	Sd(mm)	2.4	2.4	9.0	1.8	1.8	5.6
KHE		6.356097	29.702675	64.290	6.35615	29.702707	64.332
	Sd(mm)	2.6	2.5	10.8	1.9	1.9	6.7
KIEM		38.434334	0.698105	167.470	38.434265	0.697926	167.520
	Sd(mm)	2.5	2.5	8.3	1.9	1.9	6.1
LAP		52.166506	56.399964	27.885	52.166561	56.400129	27.883
	Sd(mm)	2.5	2.5	8.1	1.9	1.9	5.7
TAI		47.661912	17.081074	5.961	47.662155	17.081066	5.952
	Sd(mm)	2.4	2.4	8.5	1.8	1.9	5.6

Table 4. Coordinate-change and its standard deviations

Station	dLat/Sd(mm)	dLon/Sd(mm)	dSh/Sd(mm)	dH/Sd(mm)
CAM1	11.0 +/-3.0	-3.3 +/-3.0	11.5 +/-4.2	-32.0 +/-10.6
KHE1	1.6 +/-3.2	0.9 +/-3.1	1.8 +/-4.4	42.3 +/-12.7
KIEM	-2.1 +/-3.1	-5.3 +/-3.1	5.7 +/-4.4	49.6 +/-10.3
LAP1	1.7 +/-3.1	4.9 +/-3.1	5.2 +/-4.4	-1.3 +/-9.9
TAI1	7.5 +/-3.0	-0.2 +/-3.1	7.5 +/-4.3	-8.9 +/-10.2

as follows:

- CAM1 station can have a horizontal motion during the two observations. There is no evidence of horizontal movement at the other station.
- Although the precision of height determined by GPS is worse than the horizontal component's one, we can see an uplift of KHE1 and KIEM stations and a subsidence of CAM1.

5. Conclusions

- Quang Tri GPS network was established carefully, it's points and configuration are satisfied with the requirements of study of recent crustal movement along the Cam Lo fault.
- CAM1 station can have a horizontal motion during the two observations. There is no evidence of horizontal movement at the other station.
- Although the precision of height determined by GPS is worse than the horizontal component's one, we can see an uplift of KHE1 and KIEM stations and a subsidence of CAM1 one. Based on data Table 4. and movements of Figure 1. it is assumed that the Cam Lo fault appears to be active in the present day. The subsidence of N block (CAM1, TAI1) and the uplift of SW one (KIEM, KHE1) are not only useful, but also very important in a geophysical interpretation of CAM lo fault for geologist-specialists.

This seems to be an encouraging result in studying the activity of faults in Vietnam.

Acknowledgment

Thanks to colleagues of Institute of Geological Science for data collecting in field work, and thanks to KOSEF for POST-DOC support.

References

1. Becker, M., P. Neumaier; E. Reinhart, H. Seeger; N. T. Yem: D.C. Cong, T. Linh, T.D. To, "GPS Measurements of Crustal Movements at the Red River fault in Vietnam, The GEODYnamics of S and SE Asia (GEODYSSEA) Project," Scientific Technical Report STR98/14, GeoForschungs Zentrum Postdam, pp. 185-190.
2. Duong Chi Cong, and K.L. Feigl, "Geodetic Measurement of Horizontal Strain across the Red River

fault near Thac Ba", Vietnam, 1963-1994, Journal of Geodesy, 73, 1999, pp. 298-310.
3. GPSurvey Software User's Guide, Trimble Navigation, Sunnyvale, Calif., 1995.
4. Nguyen Danh Soan, "Specific characteristics of Earth crust's structure in Northern Central part of Vietnam,", Tap chi CAC KHOA HOC VE TRAI DAT (T. 19), 4/ 1997, pp. 337-342, Hanoi, Vietnam.
5. Simons W.J.F., B.A.C. Ambrosius, R. Noomen, D. Angermann, P. Wilson, M. Becker, E. Reinhart, A. Walpersdorf, C. Vigny, "The Final Geodetic Results of the GEODYSSEA project: The Combined Solution,", The GEODYnamics of S and SE Asia (GEODYSSEA) Project, Scientific Technical Report STR98/14, GeoForschungs Zentrum Postdam, 1998, pp. 27-38.
6. V.Q. Hai, T.D. To, D.C. Cong, "Discussion on duration of session from analysing data of GPS network," Tap chi cac khoa hoc ve Trai dat (T. 20), 3/1998, pp. 200-204, Hanoi, Vietnam.
7. Teruyuik K, K. Nakajima, "Regional Crustal Movements in Japan and Geodesy by Space Techniquiees", Journal of the Geodetic Society of Japan, Vol. 35, No. 2,1989, pp. 171-185
8. Athanasios D., "A Method for the Determination of Crustal Deformation Parameters and their Accuracy from Distance,", Journal of the Geodetic Society of Japan, Vol, 40, No. 1, 1994, pp. 19-24
9. Ahanasios D., E.W. Gafarend, "The Finite Element Approach to the Geodetic Computation of two-and-three dimentional Deformation Parameters: A Study of Frame Invariance and Parameters Estimability", Proc,. 5th International Conference CARTOGRAPHY-GEODESY, 1992, pp. 1-13
10. Kang, J.M., Y.W. Lee, "The Analysis of Earthquake Data and the GPS Baseline Change for Curst Movement", 대한토목학회논문집, 제20권, 제3-D호, 2000, pp. 341-350
11. Kang, J.M., Y. W. Lee, S.H. Song, J.D. Lee, "The Determination of Crustal Deformation Parameter by GPS Baseline Change", 대한토목학회논문집, 제20권, 제 1-D호, 2000, pp. 107-114