34

With the compliments of the authors.
Dr. Punya Charusiri
No. 38

CCOP / TP 27

Coordinating Committee for Coastal and Offshore Geoscience Programmes in East and Southeast Asia (CCOP)

Technical Meeting on Exodynamic Geohazards in East and Southeast Asia

October 2000

Preliminary Results of Paleoseismic Studies on the Mae Ai Segment of the Mae Chan Fault Zone, Chiang Mai, Northern Thailand

Suwith Kosuwan[1], Preecha Saithong[1], Apichard Lumjuan[1], Isao Takashima[2] and Punya Charusiri[3]

[1]*Geological Survey Division, Department of Mineral Resources, Thailand*
E-mail: suwith@dmr.go.th
[2]*Research Institute of Materials and Resources, Akita University, Akita, Japan*
E-mail: takasima@ipc.akita-u.ac.jp
[3]*Department of Geology, Chulalongkorn University, Thailand*
E-mail: cpunya@chula.ac.th

Abstract

Most paleoseismic studies have dealt with surface faulting from past events. Geomorphological features together with geochronological information can provide cryptic data for paleoearthquake events . The Mae Ai segments of the Mae Chan Fault Zone (MCF), Chiang Mai, northern Thailand, displays a surface rupture about 14 km long. Morphotectonic evidence within the fault segment indicates the presence of the stream terrace with the deflection of about 7 m in a left-lateral sense along the synthetic fault, and about 95 m along the main MCF.

A trench at Ban Hat Chom Phu was excavated in the alluvial fan/reworked colluvium displaced by Pleistocene and Holocene left-lateral strike-slip, synthetic fault with the reverse offset striking N 70°- 85 ° E and dips 65 °- 85 ° N. This area shows the offset-stream features and the most prominent and well-preserved fault scarp. The synthetic fault displaced young Quaternary alluvial fan surfaces and recent active stream channels. In the trench, a stack of three fan/reworked colluvial deposits with a gravel- sand- clay sequences were recognized as fault-scarp derived sediments. These sediments are affected by subsequent faulting with a 20-cm vertical slip in a reverse sense and a 7 m lateral slip in a left lateral sense. It is estimated that the deposit may have formed as a result of a seismotectonic event with an earthquake magnitude greater than 7 Richter's scale.

To constrain the timing of the deposition- related faulting event, 6 samples of the sediments in the trench were selected for thermoluminescence dating. The dates of

Keywords: Paleoseismic, Mae Chan Fault, Mae Ai segment, Chiang Mai, Thermoluminescence dating

sedimentary strata in the vicinity of the synthetic fault vary from ca. 35.3 ± 4.99 to 15.6 ±1.73 ka. Ages of the coeval seismotectonic events indicate that four probable faulting - related earthquakes occurred during 35,000, 33,000, 17,000, and at least 17,000 years ago.

1. Introduction

Thailand has not been considered to be a seismically active country due to the disappearance of large earthquakes in the past. However, northern Thailand has been subject to minor to moderate damages during historical period. Stronger earthquakes frequently happened at the neighboring country borders, e.g. Myanmar, China, and Laos. Recent geologic investigations reveal that late Quaternary faults in northern Thailand appear to be characterized by long recurrence intervals of thousands, to tens of thousands of years. (See Bott et al., 1997, Fenton et al, 1997)

The Mae Chan Fault or fault zone (MCF) has been the prime target of paleoseismic study in Thailand since 1998. Well-documented evidences of at least six surface-rupturing earthquakes were encountered along the MCF during Late Pleistocene and Holocene (Kosuwan et al., 1998). With the combined application of the remote-sensing information, currently available geological data, trench stratigraphy, and geochronological information, we subdivide MCF into 5 major segments from west to east, viz. Fang segment, Mae Ai segment, Mae Chan segment, Dong Suwan segment and Chiang Khong segment (see Fig. 1). Investigations on the Mae Ai segment has been conducted for detailed paleoseismic study since early 1999. Geomorphology has been extensively applied for identifying active tectonic processes and their history.

In this paper, we present the integrated results of the Mae Ai segment of the MCF obtained from detailed field mapping, interpretation of remote sensing information along with ground penetrating radar (GPR) geophysical survey and geochronological information. Geomorphology and Quaternary geology provide the essential information for this study. Apart from several techniques applied earlier for the Ban Pong Khom site in the Mae Chan segment, Chiang Rai (see Kosuwan et al., 1998). GPR was added to this study in order to locate more precisely the location of the fault along the Mae Ai segment (see Kalong , 1999). Significantly, the thermoluminescence dating applied to soil strata has been proved to obtain reliable result in reconstruction of the past earthquake phenomena.

2. Geomorphic Setting

Geomorphic indicators of active faulting, including well-preserved fault scarps on colluvium/alluvial fan, facet spurs, linear range fronts and offset streams, are observed along the Mae Ai segment. With the application of the field investigation in combination with the Landsat TM-5 image data and the stereographic aerial photographic information, surface rupture with the total length of about 14 km was recognized at the Mae Ai segment of MCF between Mae Kok river and Huai San stream, Ban Muang Ngam (see Fig. 1). This segment of the fault is likely to extend southwards to connect with the so-called Fang segment. The Mae Ai fault segment strikes N 70°- 85° E and dips 65°- 85° N. At the Ban Hat Chom Phu site, about 13 km east-northeast of the Mae Ai township, north of Chiang Mai, this fault is clearly recognized as a 2.5 m-high south-facing scarp with a flat graben as much as 50 m wide at its base. Evidence from our detailed surface mapping within the local landform indicates the presence of the dissected alluvial terrace, i.e., deflected about 7 m left laterally along the synthetic fault at Ban Hat Chom Phu and up to approximately 95 m along the main MCF.

With the well-precised estimate of the result obtained from the GPR for the location of the fault, a trench was properly excavated with the dimensions of 7 m in length and 3.5 m in depth across the fault that offset Quaternary sediments. The main objective is to expose a relatively complete record of the probably Holocene surface faulting events and to date the events as accurately as possible. Although the trench cannot be designed to make across the main MCF due to its inaccessibility and legal aspect, we can manage to excavate the trench across the synthetic fault. Results from sterograpghic aerial photographs indicate the landform of these Quaternary sediments as the well-defined alluvial fan/colluvium. We herein regard the fan morphology as an indicator of active tectonics, since the fan form reflects varying rates of tectonic processes, such as uplift of the source mountain along a range-bounding fault. The alluvial fan is, therefore, the end point of an erosional-depositional system in which sediments eroded from a mountain source were transported to the mountain front and deposited as a cone or fan-shaped body of fluvial and/or debris-flow deposits by the effect of sever seismicity (see also Bull, 1964, Yeats et al., 1997).

3. Stratigraphy and Structure in Trench

Understanding how datable deposits in fault zone and trenches relate to individual ancient earthquake events, we must understand the depositional surrounding of each horizon and its relation to fault-induced sedimentation. The history of repeated faulting is contained mainly in the stratigraphy of scarp-derived colluvial deposits and correlative graben sediments (Machette et al., 1992, Yeates et al., 1997). Therefore, Quaternary studies of exposed fault zones can provide the most definitive paleoseismological data.

A trench at the Mae Ai segment (Ban Hat Chom Phu site, located at the southern end of the segment) was excavated to produce nearly vertical exposures. The face of a trench wall was subdivided into a grid of 50 cm-square panels. Each panel was logged at a scale 1:10 to 1:20 depending on the complexity of the fault line in the panel. The corners of each panel were surveyed with a water level device.

The trench log data indicate a series of faulted alluvial fan/reworked colluvium deposits, from the oldest to youngest, as units A, B1, B2, B3, C1, and C2 and a sheared lake deposit as unit D as well as a top soil deposit as unit E. Ban Hat Chom Phu trench exposed a single fault trace that offset the 3 cycles of alluvial fan/reworked colluvium and one lake deposits. Its trench stratigraphy at the Ban Hat Chom Phu site is displayed in Fig. 2. The 3 underlying units A to C display a stack of the well-defined gravel- sand- clay layers. The normal sequence is composed of the yellow mottle gravel bed with sandy matrix in the bottom and succeed by the overlying layers of either coarse- to very coarse- grained sand bed or yellowish sandy clay. The unit C2 comprises a poorly sorted mixture of boulderly to gravelly debris facies, interpreted to occur as a result of faulting. The brown clayey silt layer of the unit D is inferred as the deposit filled in the sag - pond environment. All these units are regarded to have occurred in response to a series of paleoseismic events.

These Quaternary deposits are displaced roughly 20 cm to the north across the fault in a reverse sense. However, it is not quite certained that the unit E was cut by the fault or not, due to its massiveness and the uppermost horizon in the trench. The most probably youngest unit clearly and entirely broken by a fault, is unit D. In addition, our geomorphological investigation also revealed that the stream terrace close to the trench was also offset by the fault, giving rise to the apparent left-lateral slip of about 7 m. So based upon the ratio between the slip and rupturing length adopted by Well and Coppersmith (1994) and assumed that the earthquake- induced faulting happened only one time, we estimate the past earthquake magnitude of at least 7 Richter's scale.

4. Dating of the Units and Faulting Events

Though individual paleoseismicity can be recognized in the geologic records geomorphologically, many problems remain in interpreting the tectonic/stratigraphic records with sufficient accuracy to recognize patterns of fault characteristics useful in earthquake prediction. So in almost studies the most significant problem is obtaining an accurate chronology of past faulting events. Radiocarbon dating usually provided the primary age control (Vita-Finzi, 1992), but organic - rich materials closely related temporally and spatially to the seismic events are scarce and frequently nonexistent. The thermoluminescence (TL) and more advanced Electron Spin Resonance (ESR) methods are relatively new techniques which can be applied to constrain the timing of fault events (Sato et al., 1985, Fuguchi, 1988) using fault - gouge materials (Buhay et al., 1988, Ikeya, 1993, McCalpin et al., 1994, Lee and Schwarcz, 1993, 1994, Hiraga and Nagatomo, 1995) and faulted - related colluvial sediments (Sato et al., 1985, Forman et al., 1991). In areas where fault gouge materials are not commonly, coseismic events are determined with offset horizons and undisturbed strata lying over the predated fault. Exposure of mineral grains to radiation after burial causes increased trapped electrons in mineral that, in turn, results in luminescence upon heating. Sediments that receive prolonged light exposure prior to deposition, are particularly suitable for TL and ESR datings (Sato et al., 1985, Forman, 1989, Forman, et al., 1991, Ikeya, 1993). Minerals in the field can therefore absorb radiation from surrounding radioactive materials at a fixed rate and exhibit TL due to a total dose over geologic time.

In this study we applied the methodology for TL geochronological approach following that recommended by Takashima and Watanabe (1994) and Takashima et al. (1999). Six samples were taken from the faulted horizons in the Ban Hat Chom Phu sites and dated by TL dating technique. Two samples within the same stratum and at the opposite sides of the fault, were selected (Fig. 2). Samples HP1-5 and HP 1-6 were taken from middle part of the unit B1. Quartz separates from these two samples yield the dates of about 31.6 $\pm$ 3.35 ka, which is insignificant age, and 35.3 $\pm$ 4.99 ka. Two samples (HP1-3 and HP1-4) from the younger C1 unit displays the similarity in soil textural and mineralogical characteristics to the unit B1. The dates obtained from quartz separated from these two samples of the unit C1, are 33.6 $\pm$ 5.58 and 34.9 $\pm$ 3.53 ka. Quartz concentrates derived from sample HP 1-1 and HP 1-2 of the unit D, the youngest unit, yield the dates of 15.6 $\pm$1.73 and 17.0 $\pm$ 1.79 ka.

Taken into account the TL geochronological results and fault - related Quaternary stratigraphy, we infer that TL age estimates on these sediments document 3 periods of rapid deposition of colluvium /alluvial fan assemblage at about before 35,300, 35,300, and 34,900 years. The TL date estimate can, therefore, provide a control on the timing of four separated faulting events on the Mae Ai segment of the MCF. Although some uncertainty remains on the timing of the first faulting event which is responsible for the occurrence of the oldest faulted unit exposed in the trench, we consider that the most probable age of the unit is late

Pleistocene. Considering the location of samples in the middle part of the unit layer, the first recognized faulting event perhaps occurred during 35,300 years B.P. The second earthquake event is revealed by a period of rapid sedimentation between 35,300 and 34,900 years B.P., which we infer to be associated with increased rates of deposition immediately after faulting. The third earth tremor event, which perhaps indicate the large seismic event, is provided by the Holocene sediments deposited during 17,000 years B.P. on sag – pond landform. The strongest earthquake has triggered during 17,000 years B.P. The fourth quake phenomenon is supported by the TL age estimates on lake sediment offsetted by reverse fault. Unfortunately, we were not able to collecting sample from the uppermost horizon. Therefore, we cannot constraint on the time of this earthquake occurrence. However, considering errors associated with the TL dating, our preferred estimate of the timing of the most recent faulting event is at least 17,000 years B.P.

5. Conclusion

The recent behavior of the Mae Chan fault along the E-trending Mae Ai segment is left-lateral strike-slip with reverse movement to the north. From the trench stratigraphy, we believe that the youngest lake deposit is the sag pond feature, occurring as a result of the large fault action. Our paleoseismic study yields a strong insight that the Mae Ai segment is regarded the active fault with at least 4 times of earthquake events. Evidences of coseismic motions obtained from displaced alluvial fan/colluvium morphology, fault trace analysis, and TL dating results at the Hat Chom Phu trench, provide a crucial support that the last earthquake activity took place not before 17,000 years B.P.

Acknowledgments

This paper was supported by Department of Mineral Resources and the Thailand Research Fund (TRF). Krit Won-in is thanked for his assistance on the TL-experiment and analysis. We wish to thank Research Institute of Materials and Resources, Akita University, Japan, for allowing us to use facilities and TL dating instrument.

References

Bott, J., Wong, I., Prachuab, S., Wechbunthung, B., Hinthong, C., and Sarapirome, S. 1997. Contemporary seismicity in northern Thailand and its tectonics implications: in Proceedings of the International Conference on Stratigraphy and Tectonic Evolution of Southeast Asia and the South Pacific, Bangkok, Thailand:19-24 August 1997, p. 453-464.

Buhay, W. M.m Schwarcz, H. P., and Grun, R. 1988. ESR dating of fault gouge: the effect of grain size. Quaternary Science Review, 7: p.515-522.

Bull, W. 1964. Geomorphology of segmented alluvial fans in western Fresno County, California, U.S. Geol. Surv. Prof. Paper 352-E: p. 89-129.

Fenton, C., Charusiri, P., Hinthong, C., Lumjuan, A., Mangkornkarn, B. 1997. Late Quaternary faulting in northern Thailand: in Proceedings of the International Conference on Stratigraphy and Tectonic Evolution of Southeast Asia and the South Pacific, Bangkok, Thailand:19-24 August 1997, p.436-452.

Forman, S. 1989. Application and limitation of thermoluminescence to date Quaternary sediments. Quat. Int., 1: p. 47-59.

Fuguchi, T. 1988. Applicability of ESR dating using multiple centers to fault movement- The case of the Itoigawa - Shizuoka tectonic line, major fault in Japan. Quaternary Science Reviews, 7: p. 509-514.

Hiraka, S. and Nagatomo, T. 1995. How to confirm the "complete zeroing" in TL dating of fault movement- a case of the Higashiura Fault, Awaji Island in Japan. Bull. Nara Univ. Educ., 44, 2: p.17-25.

Ikeya, M. 1993. New Application of Electron Spin Resonance: Dating, Dosimetry, and Microscopy. World Scientific. London, 500 p.

Lee. H. K. and Schwarcz, H. P. 1993. An experimental study of sheared - induced zeroing of ESR signals in quartz. Applied Radiation Isotope, 44: p. 191-195.

Lee, H.K. and Schwarcz, H.P. 1994. Criteria for complete zeroing of ESR signals during faulting of the San Gabriel fault zone, southern California. Tectonophysics, 235: p. 317-337.

Kosuwan, S., Charusiri, P., Takashima, I., and Lunmchuan, A. 1998. Active tectonics of the Mae Chan Fault, northern Thailand. Ninth Regional Congress on Geology, Mineral and Energy Resources of Southeast Asia-GEOSEA'98, 17-19 August 19987, Kuala Lumpur, Malaysia, p. 234-235.

Machette, M., Personics, S., and Nelson, A. 1992. Paleoseismology of the Wasatch fault zone-a summary of recent investigations, conclusions, and interpretations, in assessment of regional earthquake hazards and risk along the Wasatch Front, Utah. U.S. Geol. Surv. Prof. Pap. 1500-A: p. 1-72.

McCalpin, J., Forman, S.L., and Lowie, M.V. 1994. Reevaluation of Holocene faulting at the

Kayville site, Weber segment of the Wasatch fault zone, Utah. Tectonics, 13 (1): p. 1-16.

Sato, T., Suito, K., and Ichikawa, Y., 1985. Characteristics of ESR and TL signals on quartz from regions, ESR Dating and Dosimetry, IONICS, Tokyo.

Takashima, I., and Watanabe, K. 1994. Thermoluminescence age determination of lava flows-domes and collapsed materials at Unzen volcano, SW JAPAN. Bull. Volconol Soc. Japan, 39(1): p. 1-12.

Takashima, I., Charusiri, P., Kosuwan, S., and Won-in, K. 1999. TL-dating results on the Mae Chan Fault, northern Thailand: Constrain for Quaternary faulting: Earth and Planetary Science Letters, 25 p. (submitted).

Vita-Finzi, C., 1992. Radiocarbon dating of the late Quaternary fault segments and systems, Journal of Geological Society, London, 149: p. 257-260.

Wells, D.L., and Coppersmith, K.J. 1994. New empirical relationships among magniture, rupture width, rupture area, and surface displacement. in Bulletin of the Seismological Society of America, V.84 : p. 974-1002.

Yeates, R., Sieh, K., and Allen, C. R. 1997. Geology of Earthquakes, Oxford University Press, London, 576 p.

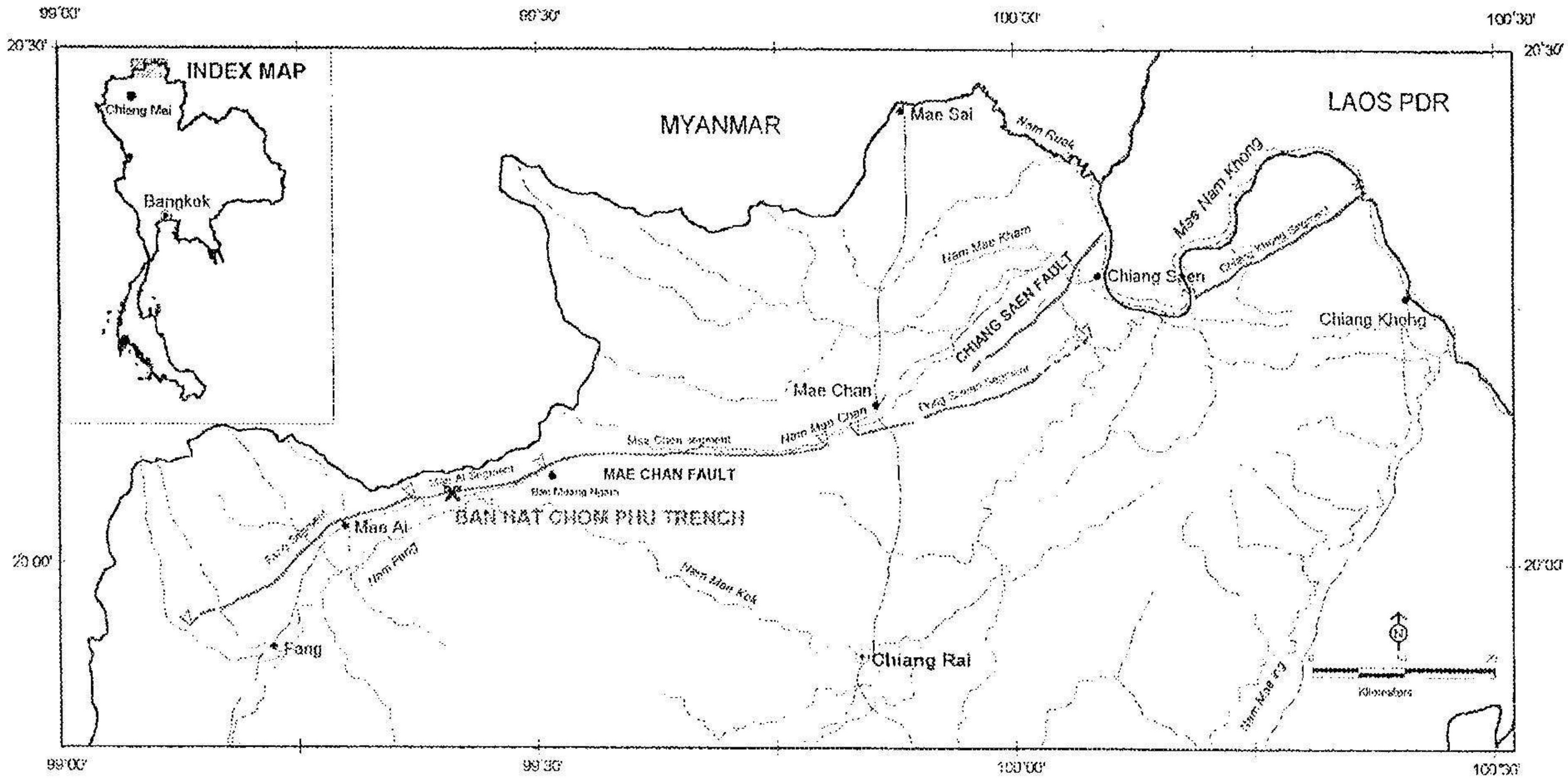

Fig 1. Location of Ban Hat Chom Phu trench site, southern part of Mae Ai segment of Mae Chan Fault, Chiang Mai, Northern Thailand.

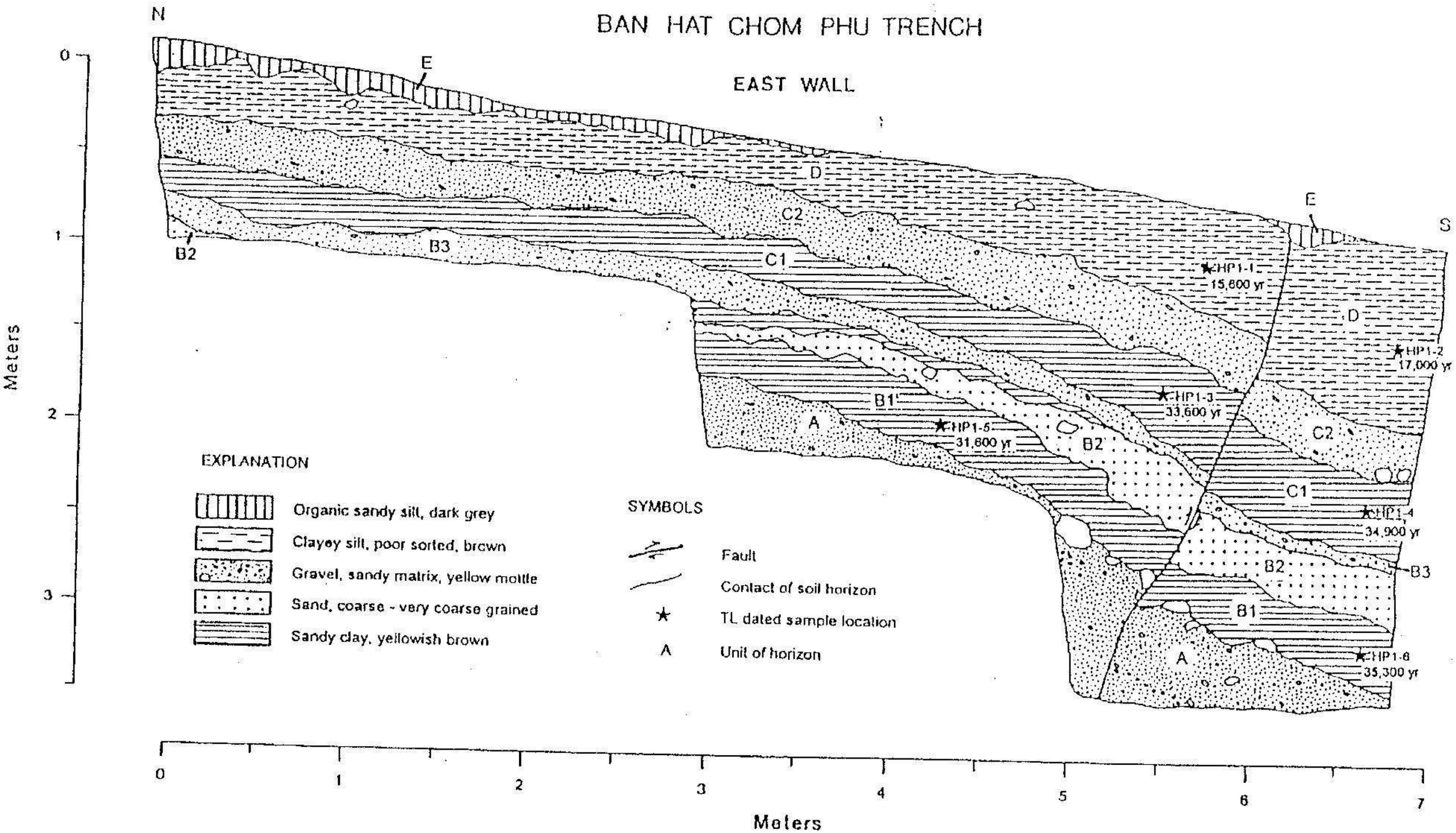

Fig.2. Trench stratigraphy of the east wall side of the Ban Hat Chom Phu trench showing reverse fault movement and locations of samples for TL dating and their dates.