CHAPTER III

THREE PAGODA FAULT

3.1 Background

There are several important major faults in several regions in Thailand, some of them are related to earthquakes historically and instrumentally (see Nutalaya et al., 1985, Hinthong, 1995). Among these faults,Three Pagoda Fault Zone (TPFZ) is one of the faults laying in the western Thailand passing Kanchanaburi (Siribhakdi, 1985). Many Thai and oversea geoscientists have referred to this TPFZ, but less of them has been researching in detail for this fault.

The study of the major faults has been recorded since 1976. Bunopas (1976) in his study on Paleozoic rocks complied the geological map in Changwat Kanchanaburi and Suphan Buri. The Geological map of Suphan Buri (ND 47-7) recorded a fault in the western Thailand named Three Pagoda Pass Fault Zone. Later, Michell (1977) referred to the Three Pagoda Pass Fault in the study of tectonic setting for emplacement of Southeast Asia tin granitoids. Then, Ridd (1978) mentioned the Three Pagoda Fault in his paper, "Thailand", which appeared in the book under the title "Phanenrozoic Geology of the World: II The Mesozoic".

There are some more researchers who are interested in the study of TPFZ as demonstrated below.

Bunopas (1981) studied paleogeographic history of western Thailand and adjacent part of mainland Southeast Asia with a plate tectonic interpretation model, and referred TPF as the Three Pagoda Pass Fault as one of the major faults in Thailand. In 1983, Bunopas & Vella had studied the tectonic and geologic evolution of Thailand and changed the Three Pagoda Pass Fault to Three Pagoda Fault (or TPF) whose orientation is in the NW-SE lineament.

Nutalaya et al. (1984, 1985) stated that the TPFZ is the fault that extends from Myanmar and pass through Thailand into The Gulf of Thailand.

Siribhakdi (1985) proclaimed that Three Pagoda Fault is still active and related to the past 1500-year-ago earthquake.

Many EGAT's geologists (such as Klaipongpan et al., 1986 and Hetrakul et al., 1986) have studied TPFZ within the specific areas, particularly those associated with Khao Laem and Srinagarind Dams, since 1980 to present. They believed TPFZ passing through both dams but seem to be less effect for those dam sites.

Shrestha (1987) investigated the active faults in Kanchanaburi Province. His research study shows that TPFZ is stilling active.

In 1988, Polachan declared that the Three Pagoda Fault Zone (TPFZ) is a NW-SE trending fault which is truncated by the Sagaing Fault Zone (SFZ) in Myanmar. The TPFZ extends from eastern Myanmar across the Thai-Malay Peninsula, through the Gulf of Thailand, before bending to a N-S direction then regaining the NW-SE trend again in the Malay Basin (Figures 3.1 and 3.2). Most workers inferred that the dominant motion of the TPFZ has been left-lateral during the Tertiary. Tapponnier et al. (1986) suggested that the Gulf of Thailand was initiated by sinistral movement on the TPFZ. They also suggested that the TPFZ has changed its sense of movement to dextral during the late Cenozoic.

Chuaviroj (1991) mentioned that the TPFZ are the faults almost parallel to Mae Ping Fault Zone and to Sisawat Fault Zone in the NW-SE direction. The TPFZ joins the Sagaing Fault in Myanmar at Sankhaburi district and has runs southward along Mae Nam Khwae Noi passing Ratchaburi Province till reaches the Gulf of Thailand in Samut Songkram Province. It is believed that the TPFZ performs the left lateral with the total estimated length of 350 km.

Hinthong (1997) noted that the Three Pagoda Fault Zone is potentially active fault zones based upon his field investigation and data compilation.

Tulyatid (1997) demonstrated that the aeromagnetic total field data for the survey area also highlight the major structures, i.e., the Three-Pagoda (TPFZ) and Mai Ping Fault Zones (MPFZ). The magnetic data clearly indicate that the TPFZ runs from approximately 98° 30' E and 15° 00' N, passed Changwat Kanchanaburi, Pathum Thani, Samut Sakhon, and continues to the Eastern Coastal part. This evidence may indicate that the Three-Pagoda fault plane dips to the NNE direction (Figure 3.3). The data also reveal a possible subsurface NW-trending fault zone within the Chao Phraya Central Plain (Figure 3.4), i.e., at approximately 15° N and 100° E.

As descried in the first chapter, remote - sensing methods can be effective in detecting, delineating, and describing neotectonic features and character of active faults. The most effective methods accentuate fault scarps by employing digital enhancement process to image analysis (see Charusiri et al., 1996) or using illumination ages, wave lengths or stereographic effects (Slemmons, 1986). Some of the methods for earthquake - hazard analysis are summarized by Glass and Slemmons (1978) and Williams (1983).

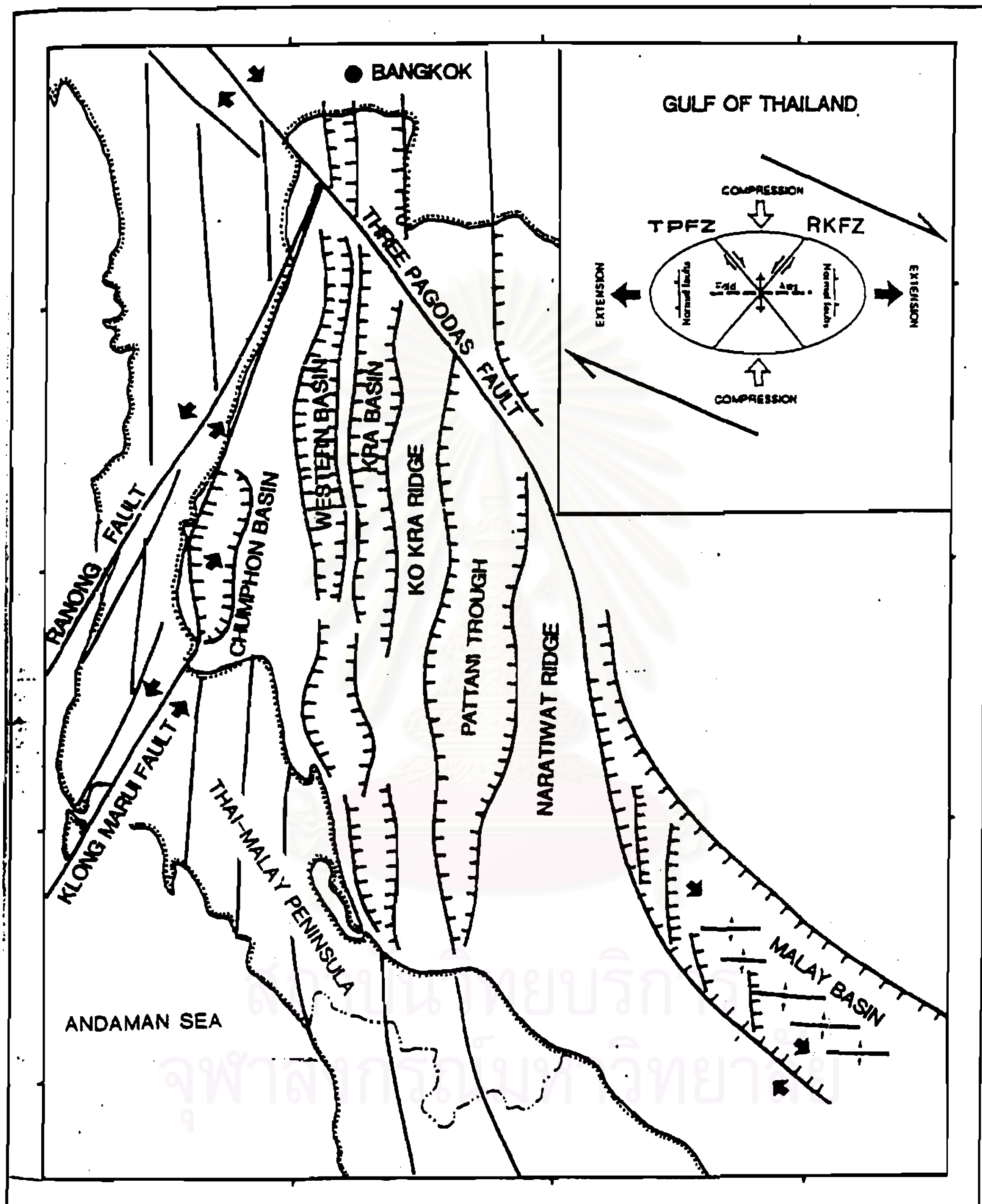

Figure 3.1 Structural map of the Gulf of Thailand and the dextral transtensional shear model (modified by Polachan, 1988).

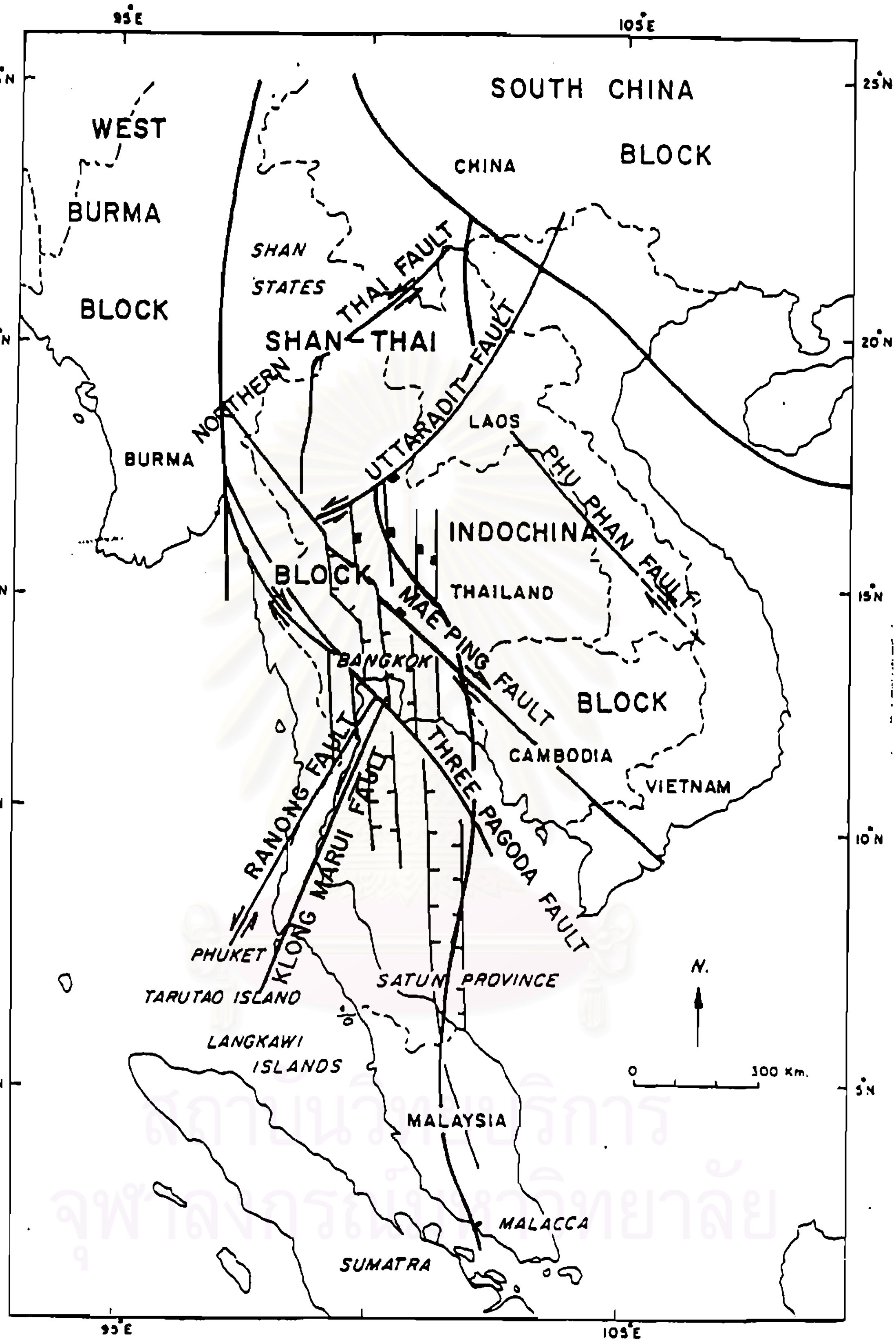

Figure 3.2 General tectonic map of Thailand showing the main fault patterns (modified by Polachan, 1988).

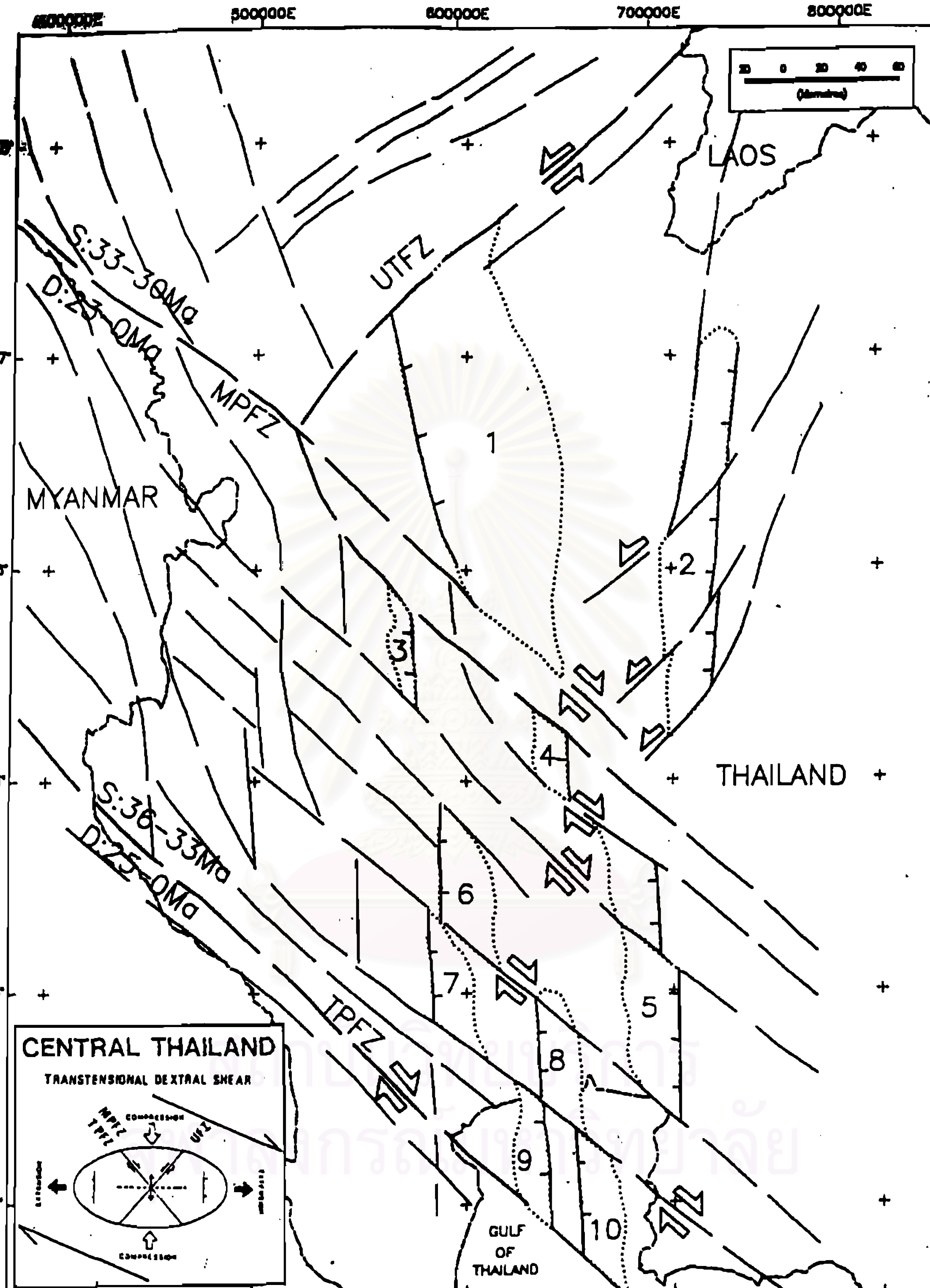

Figure 3.3 Suggested structural map of Central Thailand showing relationship between conjugate strike-slip faults and the development of N-s trending pull-apart basins, which can be related to the transtensional dextral shear model (inset). Basins in the area are 1=Phitssnulok; 2=Petchabun; 3=Lad Yao; 4=Sing Buri; 5=Ayuthaya; 6=Suphan Buri; 7=Kamphaeng Sean; 8=Thon Buri; 9=Sakhon; and 10=Paknam; S=Sinistral; D=Dextra (Tulyatid, 1997).

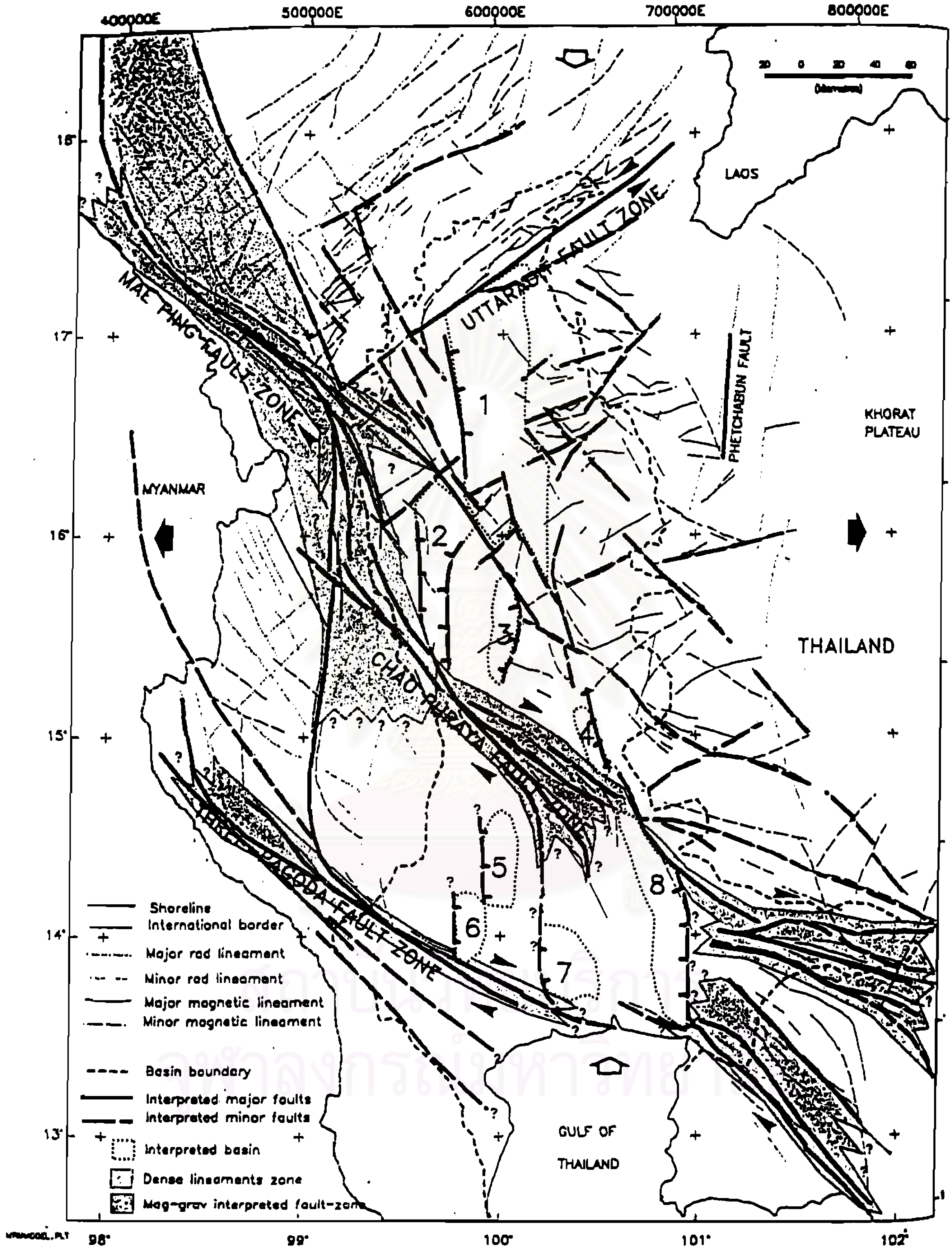

Figure 3.4 Combined magnetic-radiometric-gravity data interpretation map of the Central Plain with magnetic lineaments underlain. Sedimentary basins: 1=Phitssnulok: 2=Nong Bua; 3=Nakhon Sawan; 4=Lop Buri; 5=Suphan Buri; 6=Kamphaeng Sean; 7=Thon Buri; 8=Ayuthaya (Tulyatid, 1997)

Low-sun and radar imagery methods are especially effective in detecting and delineating neotectonic deformation. As noted by Slemmons (1986), the enhanced images can have advantages of relatively low cost, optimum scale, highlighting / shadowing of scarps by selection of appropriate solar azimuth and reliable altitude. Since this is the most effective single method of assessment of neotectonic structures and active faults, it is one of the most widely-used method for reconnaissance study (see also Glass and Slemmons, 1978). Radar imagery may have the advantages of some ground penetration in arid regions and can be taken at any azimuth, time of day or night, and in cloud or fox covers (Slemmons, 1986).

Recent studies using ground penetrating radar for fault trace identification have been very successful. Black et al. (1983) studied an area along the San Andreas Fault that has been extensively trenched and observed a good correlation between the ground penetration radar records and the trench logs. Bilham and Seeber (1985) applied subsurface radar profiling to detect colluvial wedges associated with former movements along the Lost River Fault and wide zone of faulting along the San Andreas Fault. As this method can be digitally refined, it will become a more powerful method of neotectonic as well as active or non-active fault detection and delineation in the future (see Charusiri et al., 1996).

Present study

Based upon the satellite interpretation of Landsat TM5 (scale 1 : 250,000, 1: 50,000) and JERS SAR (scale 1 : 500,000) there are 4 principle lineaments-that are NW-SE, NE-SW, N-S, and E-W. The NW-SE lineament has its estimated continuous length of 10-50 km, and also almost dip to the same direction. This lineament is the main lineament of this group. The NE-SSW lineament is rather discontinuous with the average length of 2-10 km, and shows less prominent than the NW-SE one. The N-S lineament is about 2-10 km long and rather discontinuous. The E-W lineament is approximately 2-20 km continuously long.

Most of the lineaments have cut through many kinds of rocks from the periods of Paleozoic, Mesozoic, and Cenozoic. In the Cenozoic, there is a lineament that is parallel to the basin, such as the basin in Khao Laem reservoir or the basin in Thong Pha Phum area. Moreover, there is also the lineament passing the alluvial deposit in the Ban Lad Ya area in the northern part of Kanchanaburi. Several lineaments are parallel to the streams or rivers, for example, parallel to the Mae Nam Khwae Noi and Mae Nam Khwae Yai. Sometimes, there exists the lineaments that cross-cut the streams and rivers, for instance, in the Ban Kaeng Sarawat, and Ban Chong Khaep area in Amphoe Sai Yok (in the middle part of investigation area. The NE-SW lineaments cutting thorough Khwae Noi River that runs southeastward is found as the good example evidence.

The TPFZ in Kanchanaburi study area, orients in the NW-SE orientation and are approximately 222 km long. Based upon the geophysical data (Tulyatid, 1997) it is quite possible that the TPF passes Ratchaburi and Samut Sakorn and Samut Prakan Provinces, which is located just south of Bangkok.

3.2 Theoretical Approaches

As stated in the first chapter, studies on neotectonics require basic geological information together with the precise and accuracy of data involved. At present there are several geosciencetific approaches which can help in clarifying and enhancing neotectonic analysis. The widely-accepted approaches are described in more detail by several geoscientists (see MacCalpin, 1996). Table 3.1 summarizes techniques widely used in neotectonic analyses. Followings are the general approaches or methods that can be applied to TPFZ and the other fault zones in Thailand.

3.2.1 Geodetic Approaches

Recognition of activity along some faults is quite possible by repeated geodetic surveys. Geodetic methods are capable of detecting and measuring tectonic strain of regions or across active faults. Reduction of the geodetic data permits determination of rate and direction of ground movement. The data can provide a measure of fault displacements, both seismic or aseismic, and can assist in locating active branch faults or focus on areas of current movement within complex zones of faulting. Sylvester (1986) presents several methods of near-field geodetics including level lines, alignments surveys, trilateration, triangulation, and creepmeters. Regional geodetic leveling and trilateration surveys are made to monitor regional strain accumulation and release (Prescott et al., 1979; Vanicek et al., 1980).

Advance using satellite geodesy, e.g., the Navstar Global Positioning System (GPS), offers surveying techniques with a precision superior to classic surveying at one-twentieth the cost (Kerr, 1985).

Table 3.1 A summary of widely-accepted approaches for acquiring local regional neotectonic data (modified after Stewart and Hancock, 1994).

Approach	Local	Regional
Geodetic	Triangulation tiltmeters, strain gauges, creepmeters	Global positioning system, very-long-baseline-interferometry, satellite laser ranging
Seismological	Microearthquake network	Worldwide seismological network
Remote sensing	Aerial photographs	Thermal imagery, radar imagery digital imagery
Geophysical	Electromagnetism	Seismic reflection, gravity anomalies
Geochemical	Electrical resistivity, radon emission	Hydrological monitoring
Historical	Eyewitness account, documentary evidence	Maps
Archaeological	Offset man-made structures	Prehistoric earthquake catalogues
Geomorphic*	Fault-generated landforms	Morphometric indices, drainage patterns
Geological*	Trenching	Palaeostress analysis

* including geochronological approach

3.2.2 Seismologic Approaches

Detailed studies of earthquake epicentral and hypocentral distributions of many fault zones can indicate the activity, continuity, location, dip and strike, seismogenic depth, and possible stress regime of the fault zone. However, this is often a difficult task. The quality of seismic data must be scrutinized and well understood. The best-quality data come form dense seismometer networks that are limited to a few areas and are often temporary (M. Hashimumi, 1999, per. communication). Quarry blasts and possible geothermal, volcanic, and reservoir-induced seismicity must be separated from fault-related seismicity and can be analyzed as an additional seismic hazard. The remainder may by a well-defined zone of activity or a diffuse pattern of distributed activity. Well-defined zones of activity are common in aftershock areas and along creeping sections of faults. Diffuse patterns are harder to interpret but at least indicate that some strain is taking place in the area. A diffuse pattern of historical seismicity suggests a maximum historic earthquake (for the area including the fault) and warrants further investigation of faulting in the area. Additionally, Yonekura (1975) studied Quaternary tectonic movement in the outer arc on southwest Japan with special reference to seismic crustal deformation. Matsuda et al. (1989) analyzed near-surface feature of a thrust fault moved at the time of 1896 Riru-u earthquake in Japan.

Earthquake activity along a fault zone clearly indicates that the fault zone is active at least at depths. However, the type of activity needs to be evaluated to assess the hazard and risk. According to Slemmons and Depolo (1986), a fault that slips aseismically represents a different type of risk that a fault that slips with large rupture events. Adjoining sections of the same fault may behave differently and, for example, the San Andreas Fault between Parkfield and San Juan Bautista appears to be characterized by creep and frequent lower magnitude (less than 6) earthquakes, whereas the adjoining section to the south has abrupt brittle failures, about 150-yr recurrence intervals, and up to magnitude 8.3 earthquakes.

3.2.3 Remote Sensing Approach

Synthesis using remote-sensing data and interpretation such as aerial photographs, satellite image analysis, can greatly assist in neotectonic studies. Aerial photographs and satellite imagery provide instantaneous coverage of the past and present-day topography and Earth's surface and, as a result, are useful reconnaissance tools, permitting local or regional mapping of neotectonic structures (Rothery & Drury 1984). More ambitions use of this data can be difficult, although the much improved resolution of SPOT images has allowed more sophisticated investigations (Peltzer et al. 1989). Where images of an area subject to neotectonic deformation are available for different periods of times, comparison between them can reveal specific morphological effects of that deformation (Machette, 1987a).

In Turkey, Chorowicz et al. (1999) analyzed neotectonics in eastern North Antatolian Fault region using Synthetic Aperture Radar (SAR) imagery acquired by the European Remote Sensing (ERS) satellite and application of Digital Elevation Model (DEM) for the active fault analysis in the field.

3.2.4 Geophysical Approach

There are many geophysical tools that can be used for studying in neotectonics as presented below.

Geophysical approach both by airborne (see Tulyatid, 1997) and ground (Prescott et al., 1981, Sylvester, 1986) surveys can be used successfully for neotectonic studies in several countries.

Observations of seismicity can sometimes help to delineate active faults. Persistent alignments of seismicity especially at the ends of identified faults, can occasionally be considered seismic sources or seismogenic extensions of a fault.

In the eastern United States, alignments of high seismicity such as near New Madrid are associated active subsurface faults. Other major basement faults are associated with seismicity and may be active (Gordon, 1985); these also could be examined.

Seismic reflection techniques can help to delineate subsurface faults in sedimentary basins, both on land and beneath lakes and oceans. These techniques are used for recent fault detection and delineation studies, particularly in offshore California (Greene et al., 1973) and along the central California coastal margin near the Hosgri Fault (Crouch et al., 1984) near Point Conception (Pipkin and Ploessel, 1985), and in the offshore zone of deformation between the Inglewood Fault and Rose Canyon Fault (San Diego). Seismic reflection profiling by the Consortium for Continental Reflection Profiling (COCORP) has revealed the down-dip nature of many faults and a major detachments surface under the Sevier Dese of Utah (Allmendinger et al., 1983).

Gravity methods are most effective for studying fault zones where a strong density contrast exists between materials on either side of the fault. This situation occurs along faults where basement rocks are displaced against sediments or fault offsets in basins where the thickness of sediments differs across the fault. These methods are especially effective for regions of extensional faulting. Zoback (1983) used gravity techniques to delineate the geometry of range bounding normal faults in the Basin and Range province along the Wasatch Fault zone in Utah.

Application of surface magnetic and aeromagnetic survey methods for evaluation of active faults is discussed by Cluff et al. (1972), Krinnitzsky (1974), and Sherard et al. (1974). These methods can be used to detect and delineate faults concealed by recent sediments and provide a relatively inexpensive method of contouring the thickness of basin fill. Smith (1967) located intrabasins, largely concealed, major fault graben within the Dixie Valley graben using aeromagnetic methods. Some of these graben-boundary faults were also accurately delineated by the faulting of the 1954 Dixie Valley earthquake. Smith provided a detailed outline for applying magnetic methods to the Basin and Range province in SW USA, with normal-and oblique-slip faults. In Thailand, Tulyatid (1997) adopted the airborne magnetic and radiometric data interpretation to the concealed faults and structures in several Cenozoic basins in Thailand.

Bailey (1974) used a magnetometer to determine the surface fault location of the Chabot Fault, California, where anomalous drops in magnetism suggested locations of fracturing and subsequent leaching related to faulting. The eastern limit of the Carbot Fault zone was identified so that buildings could be sited to avoid potential surface ruptures. Similar applications may be useful in defining active faults that are concealed by young alluviums or bodies of water.

3.2.5 Exploratory Approach

Exploratory methods for fault assessment advocated by Louderback (1950) were little used until the late 1960s when they are assumed as important roles in fault evaluation to assess such features as for activity, age dating, paleorupture and liquefaction events, slip direction, recurrence intervals, and slip rates. An adequate exploratory trenching and bore hole program is critical in evaluation of active faults and is a major part of both domestic and foreign assessments. Specific applications at fault assessment are included in Taylor and Cluff (1973). The use of trenching as an exploratory method for nuclear power plant siting is discussed earlier by Hatheway and Leighton (1979).

3.2.6 Archaeological and Historical Approaches

Data compiled from both archaeological and historical approach-e.g.

eyewitness account, documentary evidences (including historical texts, annals, stone inscriptions, prehistoric earthquake catalogues and astrological document, locations of ancient city, old buildings, buried and ruined construction, offset man-made structure etc.), can provide a cryptic solution for past seismicity and neotectonic events. For example, in the Mediterranean region, assessments of earthquake incidence derived from the historical accounts and archaeological finds have been invaluable in delimiting areas of recent tectonism which have not been identified from the pattern of instrumentally recorded seismicity (e.g. Ambraseys, 1978, Nur 1991).

3.2.7 Geomorphic Approach

Sieh and Wallace (1987) adopted many evidences to unravel movement along the San Andreas Fault at Wallace Creek in California. In their investigation, the combination of geomorphic features related to faulting such as offset streams, triangular facets, fault scarps, shutter ridges etc. were used for neotectonic synthesis. In Himalaya region, northern India, Sah and Virdi (1997) combined field data, geomorphic signatures and radar image interpretation and synthesized them for studying neotectonic activity in areas along the Sumdo Fault, Spiti Valley, Kinnaur District.

The freshness of appearance and types of geomorphic expression of faults are related to the age of faulting (Matsuda, 1974 ; Slemmons, 1977, 1982; Wallace, 1977, 1987). Geomorphic investigations on faulting are relatively easy, straightforward, and can yield considerable information. Many landforms, such as depressions and sag ponds, open rifts, and prominent high-angle scarps, suggest youthfulness and further help to identify the active traces or strands of fault zones (Figure 3.5).

A geomorphic investigation begins with examination of aerial photographs for reconnaissance surveys. Overview of the geomorphology allows delineation of key locations for ground investigations. Low-sun-angle techniques for reconnaissance have been extremely useful in detecting subtle geomorphic features that would have otherwise been missed (Class and Slemmons, 1978), such as in cities where geomorphic expression of scarps may have been smoothed out or altered, but general elevation differences still exist.

Key areas found through geomorphic investigation are often used as sites for further geologic investigations as exploratory trenching. Geomorphic investigations form a large part of the data base used in paleoseismic investigations. Freshness and continuity of geomorphic expression in space strongly suggest a surface rupture created during one event or over multiple events closely spaced in time.

Recently there have been numerous efforts to quantify the degree of degradation of fault scarps relative to age.

3.2.8 Geologic Approach

Geologic method provides a direct evidence for neotectonic studies. One of the most convincing arguments or evidences of fault activity is the cross-cutting or non-cross cutting relationship with a datable unit. If Holocene activity is the criterion for activity, then a Holocence age unit crossing the fault could be an ideal location for a trench site. If the unit is offset, then the age of the unit and the amount of offset can be used to estimate a slip rate and a recurrence interval if the nature of characteristic earthquake is known. A wide variety of types of Holocene deposits have been used for evaluation of fault activity, most commonly alluvial and volcanic deposits. Deposits are dated by TL, ESR, carbon-14 radiometric methods, tephrochronology, soil development, fossil stratigraphy, and many other techniques. Exposures of faulted units may be found in stream cuts and landslide scars or in road cuts or other man-made excavations. To prove whether a fault or strand of a fault system is active, a trench may be dug (see exploratory approach) at the proposed site and the geologic units and soils inspected for faults. If no demonstrated fault activity has taken place in these geologic units within the defined "active" fault period, the proposed structure can be considered reasonably safe from damage from surface faulting.

The structural aspects of young geologic units adjacent to faults may also provide information about activity of a fault. Adjacent units may be brecciated and shattered, have open fissures, be tilted or warped, or have secondary effects of faulting and liquefaction effects (e.g., sand boils and sand dikes). In a detailed study of a fault, the youthful geologic units should be described, delineated, and inspected for evidences of young faulting.

3.2.9 Geochronological Approach

Although knowing precisely when a fault moved or a surface was tilted is critical in neotectonic studies, the evolution of the methodologies, applicability, resolutions and limitations of the multitude of dating techniques applied to the study of active tectonics, is outside the scope of this study. Instead, the reader is directed to excellent reviews of this subject by Pierce (1986) and Forman (1989).

Table 3.2 shows a summary of dating methods applied in neotectonic studies. It is noteworthy, however, the field of geochronology has undergone significant change in the last decade or so. Some well-established dating methods have witnessed important advances, such as the development of accelerator mass spectrometry (AMS), radiocarbon dating which requires a greatly reduced sample size and, therefore, has the potential for increased precision. In addition, other numerical dating techniques developed in the 1960s, such as thermoluminescence (TL), electron-spin resonance (ESR) and Uranium-series dating, have been refined and widely applied to neotectonic problems. Progressive improvement in the scope and limitations of established relative-dating methods, such as morphometric dating of fault scarps and soil development, has occurred along with a number of more recent developments, such as the use of cosmogenic isotopes and amino-acid geochronology, which show considerable potential as both relative and absolute age-dating methods, but which are only now being applied to neotectonic phenomena (Muhs 1987, Pavlich, 1987).

It is also important to note that different dating methods date different aspects of neotectonic deformation (see Tables 3.2 and 3.3). Some techniques, such as ESR, and palaeomagnetic dating of fault gouges (Grun 1992, Hailwood et al., 1992) may date actual fault movement, while other techniques, such as morphometric dating of fault scarps, and thermoluminescence of scarp-derived colluvium, record the time elapsed since a section of fault emerged at the ground surface (Forman et al., 1991).

More commonly, dating determines the ages of geological or geomorphic units offset or unaffected by fault activity (see also Figure 3.4), and, therefore, provides maximum and minimum age limits, respectively, for fault activity (Allen 1986, Lagerback, 1992). Where a number of such horizons have been disrupted at varying degrees by recurrent faulting, a chronology of deformation can be established and reveals the incidence of tectonic movements over time. This in turn, can be used to assess to what degree earthquake faulting is periodic, that is, whether it recurs over a regular and, therefore, predictable period of time. The most detailed geological record of earthquake activity, at Pallet Creek on the San Andreas fault, suggests that earthquake recurrence is not periodic but, instead, comprises clusters of earthquakes within a short time interval separated by much longer periods of quiescence (Sieh et al., 1989).

Table 3.2 A summary of geochronological methods commonly used neotectonic studies (modified after Stewart & Hancock, 1994).

	Dating method	Material dated
1. Annual	Historical records	Eye witness accounts, historical documents, legends
	Dendrochronology	Annual tree rings
	Varve chronology	Deformed lake sediments
2. Radiometric	Carbon.14	Charcoal, peat and shells from offset datum horizon
	Uranium-series	Fossil coral reefs, mollusce, bone, pedogenic carbonate
	Potassium-argon fission track	K-bearing igneous rocks, volcanic glass shards, zircon
3. Radiologic	Uranium trend	Alluvium colluvium, loess
	Thermoluminescence*	Quartz and felspar grains in fault scarp-derived colluvium
	Electron spin resonace*	Quartz-bearing fault gouge
4. Process-oriented	Amino-acid racemization	Molluscs, skeletal material, lichen on glacial moraines and fault scraps
	Lichenometry	
	Soil chronology	Degree of soil development on offset geomorphic surfaces
	Rock weathering	Rock varnish, weathering rinds
	Slope morphometry	Fault scarps and offset erosional scraps
5. Correlative	Stratigraphy	Scrap-derived colluvial wedges
	Archaeology	Post sherds and other artifacts
	Palynology	Offset glacial moraines
	Palaeomagnetism	Fault gouge

* method used in this study.

Table 3.3 Classification of Quaternary Dating Methods Applicable to Paleoseismology (McCalpin & Nelson, 1996)

Type of Result

Numerical age

calibrated age

Relative age

Correlated age

Type of Method

Calendar-year	*Isotope*	*Radiogenic*	*Chemical and Biological*	*Geomorphic*	*Correlation*
Historical records	^{14}C	Luminescence	Amino acid raceimization	soil profile development	Lithostratigraphy
Dendrochronology	K-Ar and ^{39}Ar-^{40}Ar	Electron spin resonance	Obsidian and tephra hydration	Rock and mineral weathering	Tephrochronology
Varve chronolgy	Uranium series		Lichenometry	Progressive landform modification	Paleomagnetism
	Cosmogenic isotope other than ^{14}C (^{210}Pb, ^{36}Cl)		Soil Chemistry	Rate of deposit	Fossils
			Rock varnish chemistry	Relative geomorphic position	Artifacts
					Stable isotopes

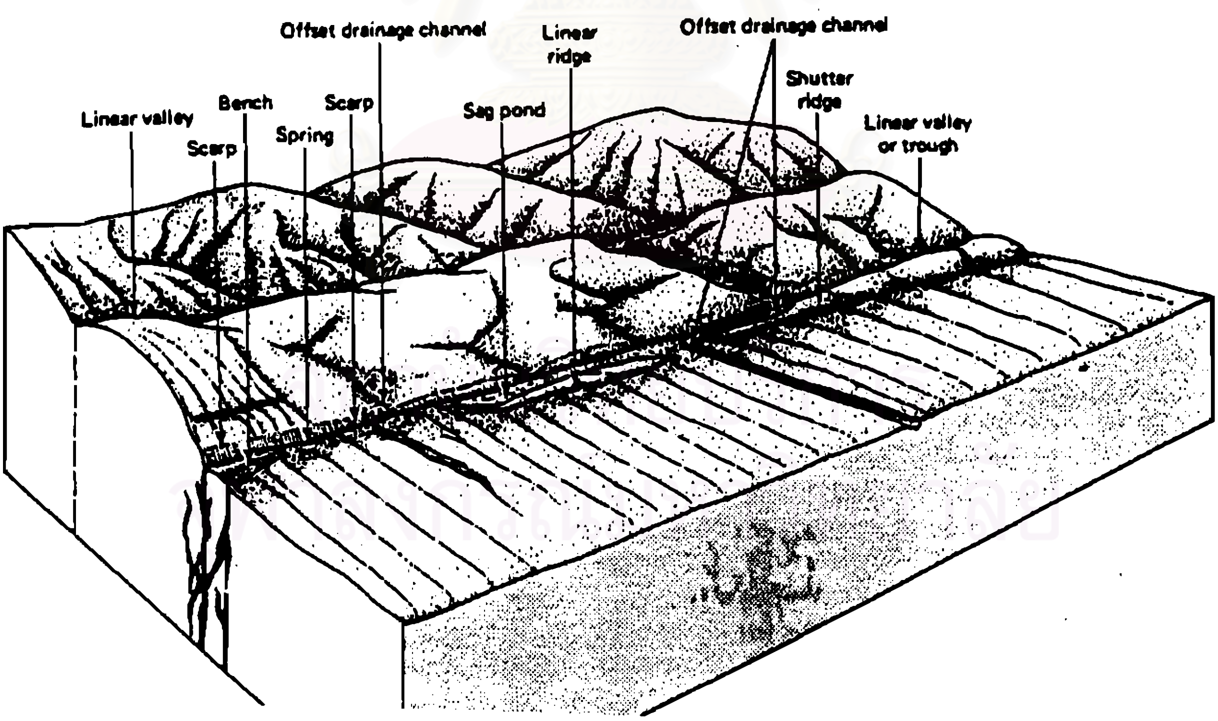

Figure 3.4 Assemblage of landforms associated with strike-slip faulting (Slemmons and Depolo, 1986)