

CHAPTER 2

GEOLOGY OF SA KAEO-CHANTHABURI ACCRETIONARY COMPLEX

2.1 Previous works – Regional Geology and its tectonic setting

The history of Asian terranes is started probably at Gondwana, southern parts of Pangea. Gondwana was created at 600-500 Ma by the fusion of East and West Gondwanas (Fig. 4). Accretion of East Gondwana completed probably by the middle Proterozoic with an addition of Australia, India, Madagascar, coastal East Antarctica, and possibly the Kalahari area of South Africa. West Gondwana completed its assembly by about 600-500 Ma and contains South America and all of Africa (north of the Kalahari region) (Rogers, 1996; Rogers and Santosh, 2003).

With regard to the recent geologic interpretation on SE Asia, two Asian terranes, the Indochina and the younger Sibumasu, drifted northward from Gondwana across the Tethys at different times. Amalgamation and accretion of Asian terranes occurred progressively during the Late Devonian to Cretaceous, beginning with the intra-Tethyan amalgamation of South China and Indochina to form Cathaysia landmass in the Late Devonian to Early Carboniferous. The Sibumasu drifted and amalgamated with Indochina of Cathaysia domain during the Latest

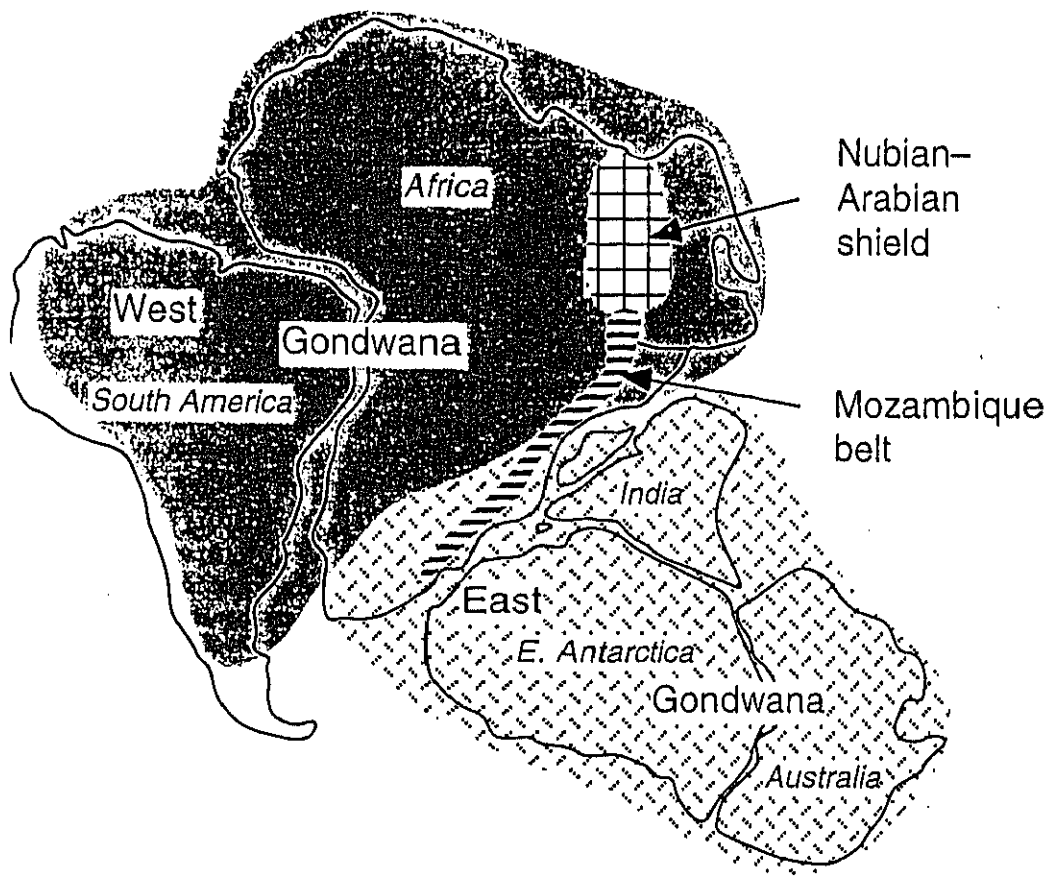


Fig. 4 Paleogeography of West Gondwana and East Gondwana (Rogers and Santosh, 2003).

Permian to Triassic (Bunopas, 1981; Metcalfe, 1988, 1999). Their continent-continent collision zone in Thailand, which represents a main Paleo-Tethys, has been traditionally named as the Nan-Uttaradit and Sa Kaeo Sutures (e.g. Bunopas, 1981; Metcalfe, 1996, 1999; Hada et al., 1997, 1999) (Fig. 1). However, Ueno (1999) redefined the Sibumasu block based mainly on the distribution of Paleo-Tethyan oceanic sedimentary rocks with Late Paleozoic foraminiferal distribution and paleobiogeographic characteristics, and recognized two other geotectonic units between the Indochina and “revised Sibumasu” blocks. They are the Sukhothai Zone of volcanic arc origin, and Inthanon Zone of Paleo-Tethys remnant (Fig. 2). Furthermore, the Nan-Uttaradit Suture has been interpreted as a remnant of the marginal sea such as a closed back arc; it is neither the Gondwana/Tethys divide nor the mutual boundary between the Sibumasu and the Indochina blocks (Ueno, 1999).

The above-mentioned investigation, however, had been mainly limited in northern Thailand. Geology and tectonic evolution in eastern Thailand is not much mentioned. Hada et al. (1997, 1999) had studied a southern segment, Sa Kaeo-Chanthaburi area, of the Nan-Uttaradit Suture in eastern Thailand. The rock assemblages in the Sa Kaeo-Chanthaburi segment comprise two parallel belts; a western belt of Chanthaburi chert-clastic sequence, and an eastern belt of serpentinite Thung Kabin mélangé (Fig 5). Generally the Chanthaburi chert-clastic sequence is characterized by alternation of red-bedded chert units and clastic units. Radiolarian fossils in chert beds indicate that all stacked chert slices was deposited in the Middle to Late Triassic. On the other hand, the Thung Kabin mélangé is characterized by strongly foliated serpentinite including various kinds of blocks. The dominant rock types of blocks are

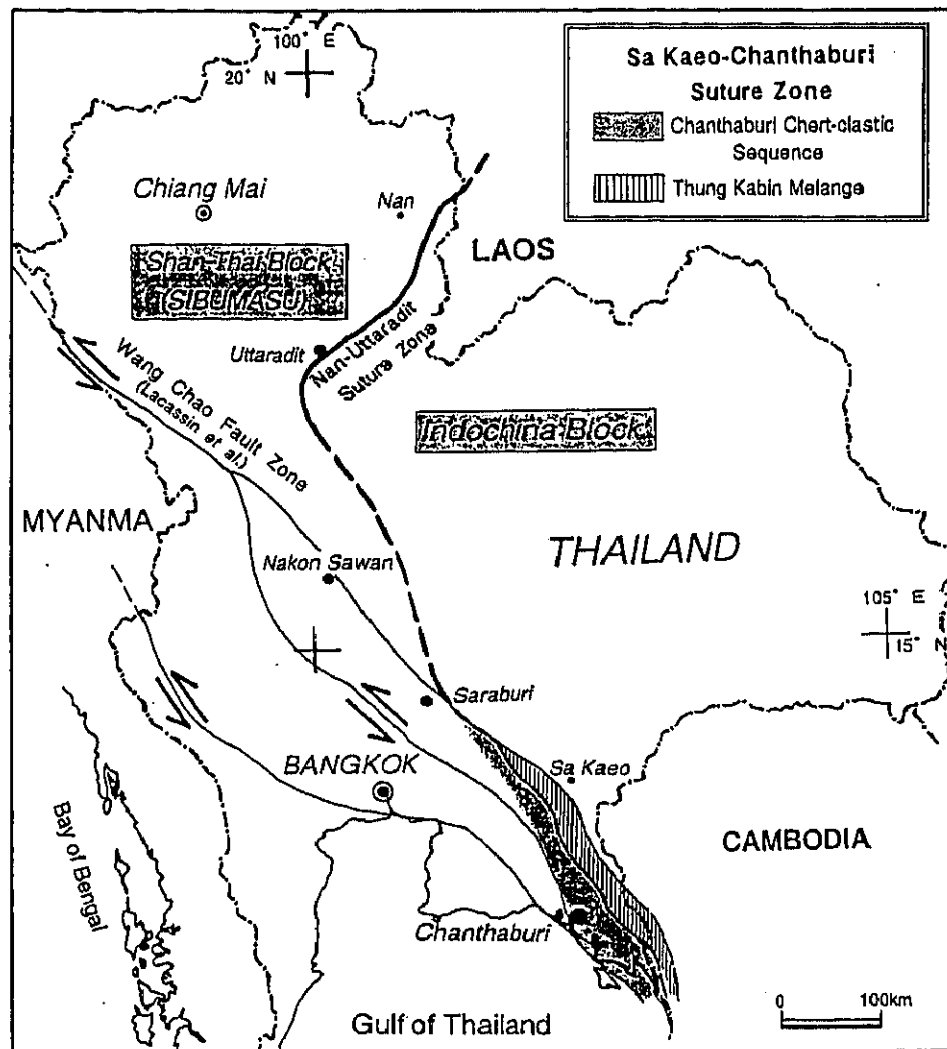


Fig. 5 Geologic outline of the Sa Kaeo-Chanthaburi suture zone showing the Chanthaburi chert-clastic sequence and the Thung Kabin mélangé (Hada et al., 1997, 1999).

greenstone, limestone and chert. Sandstone, conglomerate and granitic rock also occur as tectonic blocks. Radiolarians from chert occurring as clasts in block-in-matrix indicate Early to Late Permian, while fusulinacean fossils from limestone indicate Early to Middle Permian.

Chaodumrong (1992b) divided the Permian rocks in Rayong, Chanthaburi and Sa Kaeo, eastern Thailand into three stratigraphic units; the Pm, Pm₁ (Wung Nam Yen) and Pm₂ (Khao Taa Ngog) Formations (Fig. 6). The westernmost Pm Formation was believed to be located in the Sibumasu Block of Bunopas (1981) and Metcalfe (1988, 1999). The Wung Nam Yen Formation in the Sa Kaeo-Chanthaburi area was interpreted as thrust sheet complex of red chert, limestone and pillow lava. The stratigraphic relationship among these rocks, however, is still ambiguous. Limestone mountain ranges near the border between Thailand and Cambodia are belonging to the Khao Taa Ngog Formation. It is characterized by typical karst topography with steep and high mountains. It is correlated with limestone of the Saraburi Group belonging to Indochina Block in central Thailand (Chaodumrong, 1992b). Permian rocks in the Sa Kaeo-Chanthaburi area were covered by the Triassic greywacke unit, Pong Nam Ron Formation (Siwaboworn et al., 1976; Salyapongse, 1992; Chaodumrong, 1992b). Salyapongse (1992) and Chaodumrong (1992b) considered that the Pong Nam Ron Formation represented probably syn-collisional sediments along the remnants basin between the collision zone between Sibumasu and Indochina.

With respect to geochronological studies, granitic rocks in eastern Thailand can be subdivided into two belts, the Central and Eastern belts, out of three belts for the entire country (Pongsapich et al., 1983; Cobbing

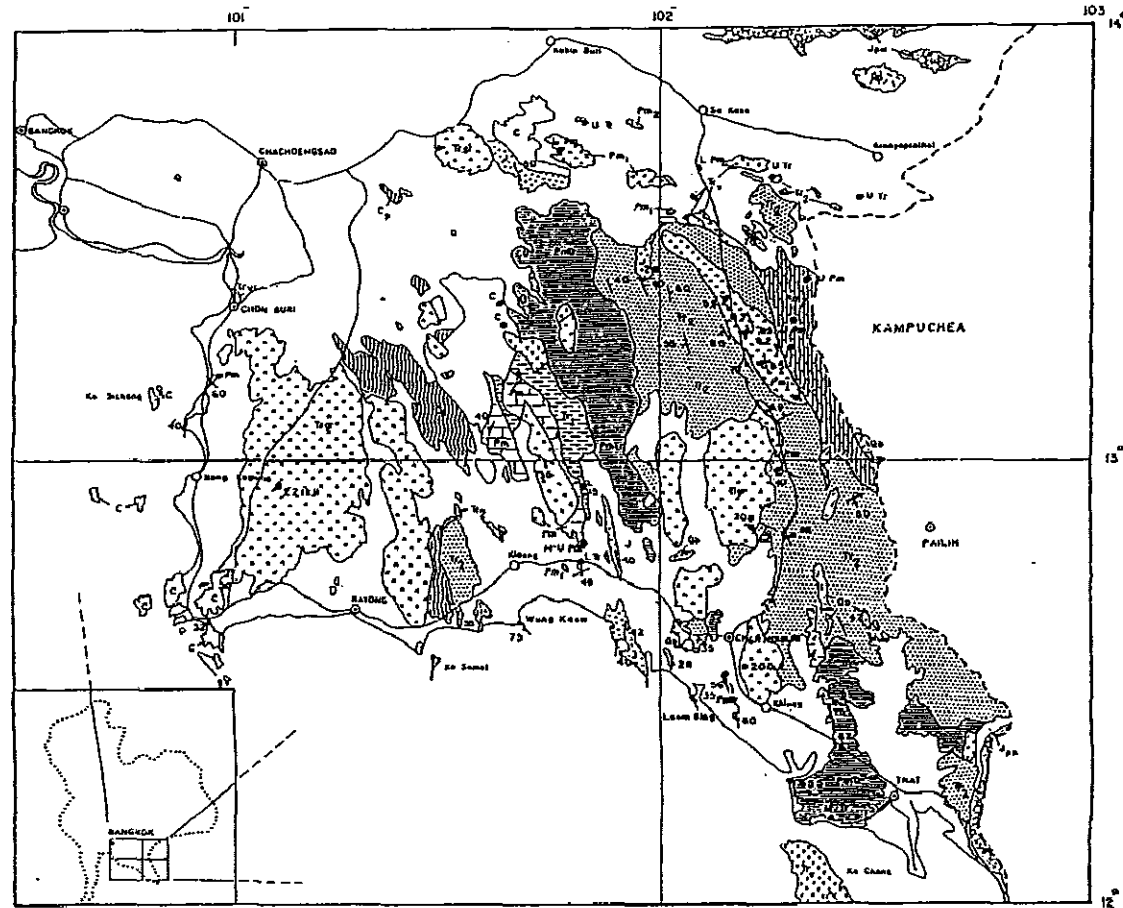


Fig. 6 Geological map of the eastern Thailand (Chaodumrong, 1992b).

GEOLOGICAL MAP EXPLANATIONS

Sedimentary and metamorphic rocks		Age
Q	Alluvial and coastal sediments	Quaternary
<i>Unconformity</i>		
T	Lacustrine sediments partly with coal	Tertiary
<i>Unconformity</i>		
J _{pw}	Phra Wihan Fm : Matured, light gray sandstone rich in quartz content, and common in cross beddings and fining upward sequences	Jurassic
J _{pk}	Phu Kra-dung Fm : Maroon mudstone and thinner beds of siltstone and sandstone, often displaying fining upward sequences and intercalation with pale green mudstone	Jurassic
J	Laem Sing Fm : Matured, red and light brown sandstone, siltstone and mudstone with minor conglomerate. Cross beddings are locally abundant.	Jurassic
<i>Unconformity</i>		
Tr ₂	Pong Nam Ron Fm : Massive bedded gray feldspathic sandstone and interbeds of thin to medium parallel bedded feldspathic sandstone and mudstone with minor conglomerate; Bouma sequences are common.	Triassic
Tr ₁	Sukpaiwan Fm : Association of shallow marine limestones, shale and sandstone	Triassic
<i>Unconformity</i>		
Pm _{3c}	Noen Po Fm : Gray to light gray feldspathic shale and mudstone; feldspathic-rich chert commonly containing radiolaria; carbonaceous shale; minor red clastics	Permian Triassic
Pm ₂	Khao Taa Ngog Fm : Massive bedded fossiliferous limestone, common fusulinids and crinoids	Permian
Pm ₁	Wang Nam Yen Fm : Thrust sheet complexes containing thin and medium bedded chert with common radiolaria, thin bedded red pelagic claystone, shallow marine limestone often containing fusulinid, and ultramafic rocks	Permian
Pm	Limestone, sandstone, shale and volcanic rocks, locally containing fusulinids and bivalves	Permian
C	Feldspathic phyllite, marble, siltstone, sandstone and mudstone with local bryozoa and forams	Carboni-ferous
<i>Unconformity</i>		
Cp	Gneiss, quartzite and schist	Carboni-ferous
Igneous rocks		
Qb	Basalts	Quaternary
Trgr	Granites	Late Triassic
Trv	Volcanics	Late Permian- Triassic

21 / Strike and dip of beds
 37 / Strike and dip of foliation and cleavage
 / Fault

36 / Strike and dip of overturned beds
 Pm • Fossil location with or without age determination
 200 ± 5 Radiometric age locality

et al., 1986; Charusiri et al., 1992, 1993) (Fig. 7). This comparison had been done based on the concept of I- and S-types which represent granitic sources derived from partial melting of oceanic crust and the acidic continental crust, respectively. Generally it is acceptable that the Central belt consists of mainly S-type accompanying local I-type, whereas the Eastern belt comprises I-type as a whole. The $^{40}\text{Ar}/^{39}\text{Ar}$ radiometric dating of these granites yielded ages of 179-220 Ma for the Central belt and 220-245 Ma for the Eastern belt (Charusiri et al., 1993).

The Soi Dao Granite (after the name of Soi Dao Mountain), covering more than 600 km² in area, intruded into the Pong Nam Ron Formation in the southwestern part of the present study area. Regarding the studies of granitic rocks in eastern Thailand subdivided into two belts, the Central and the Eastern belts (Pongsapich et al., 1983; Cobbing et al., 1986; Charusiri et al., 1992, 1993), the Soi Dao Granite is possibly belonging to the Eastern belt.

2.2 Tectono-stratigraphy of the Sa Kaeo-Chanthaburi Accretionary Complex

The Sa Kaeo-Chanthaburi (SKCB) area in eastern Thailand has been of interest in terms of tectonic construction of Thailand since several previous researches (e.g. Bunopas, 1981; Metcalfe, 1988, 1999; Hada et al., 1997, 1999) reported that it was a collision zone between Sibumasu and Indochina blocks. It is characterized by approximately NW-SE trending, mountain ranges. The study area is generally covered by a subtropical jungle with bushes and agriculture areas.

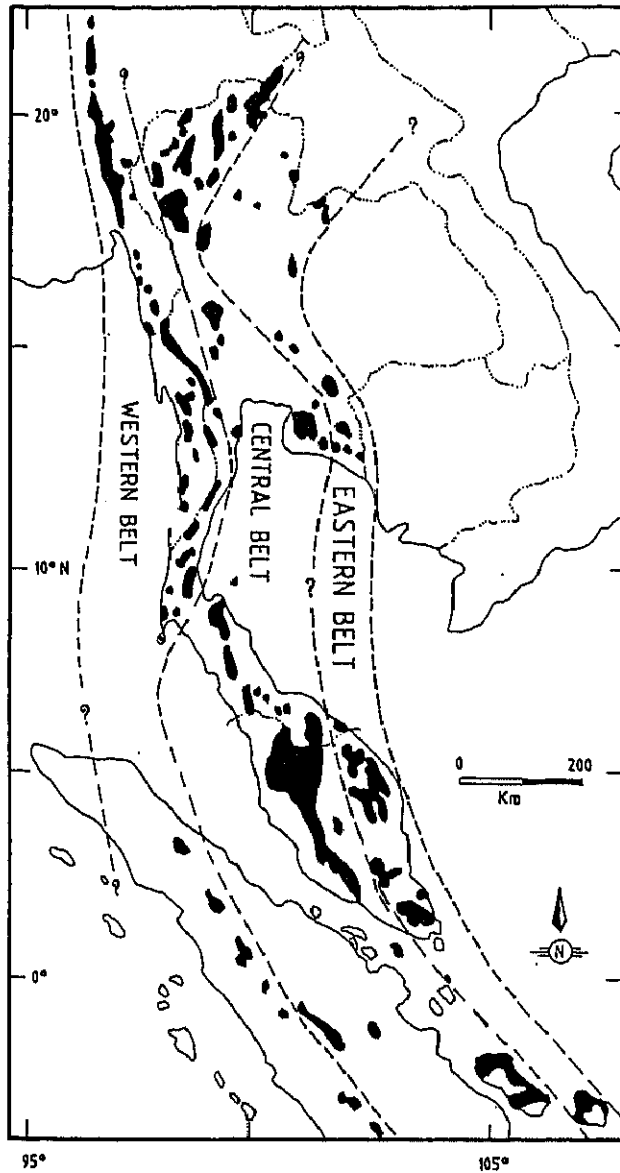


Fig. 7 Distribution of granite belts in Thailand (Charusiri et al., 1993).

Special attention was paid to the Thung Kabin *mélange* of Hada and his co-workers (see Hada et al. 1997, 1999) who published pioneer papers about applying the *mélange* concept with rock assemblages for the tectonic evolution of eastern Thailand. Hada et al. (1997, 1999) had studied the first outcrop of serpentinite *mélange* from this tectonic belt. However it is the only one outcrop that they reported in their papers.

The Thung Kabin *mélange* (Hada et al., 1997, 1999) and geology of adjacent area had been re-studied in more details. The Sa Kaeo-Chanthaburi Accretionary Complex (SKCB-AC) was proposed here instead of “Thung Kabin *mélange*” of Hada et al. (1997, 1999). The SKCB-AC extends from the southern part of Sa Kaeo province to the northern part of Chanthaburi province near the border line between Thailand and Cambodia. The SKCB-AC consists mainly of two kinds of rock assemblages, *mélanges* of oceanic plate materials and covering sediments of turbiditic sequence. *Mélange* belt of oceanic plate materials is largely a zone of chaotically mixed pelitic-matrix *mélanges*. The *mélange* contains a diverse assemblage of rocks of various sizes. The *mélange* belt is traceable for a hundred of kilometers along the strike and is up to tens of kilometer wide (Fig. 8).

Based upon the field investigation, structural relation and paleontology, the SKCB-AC can be tectono-stratigraphically divided into newly four proposed units from north to south (Fig. 9; Table 1), as described below.

- (1) Khao Prik unit;
- (2) Khao Hleam unit;

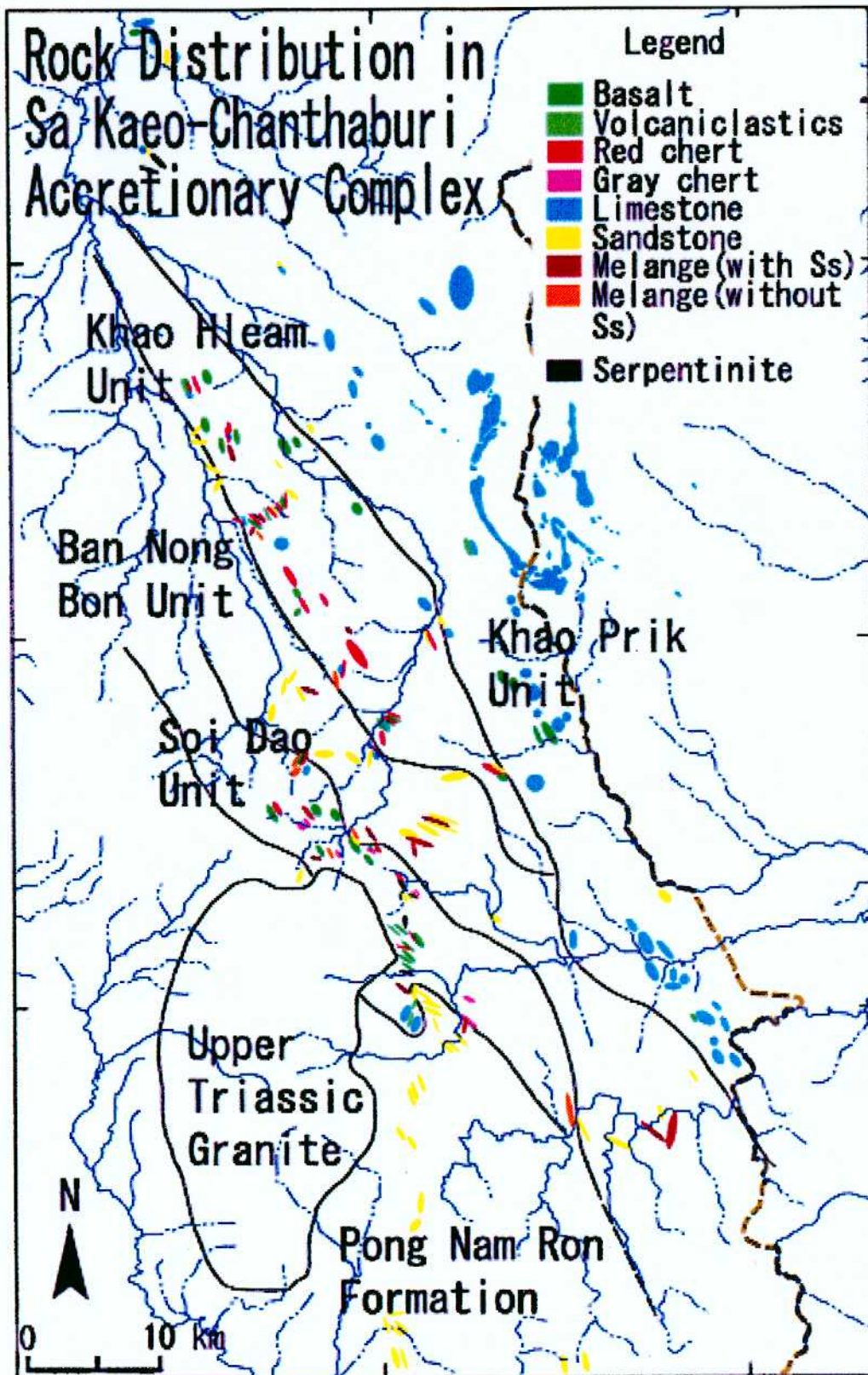


Fig. 8 Rock distribution in the Sa Kaeo-Chanthaburi accretionary complex showing characteristics of blocks in mélanges.

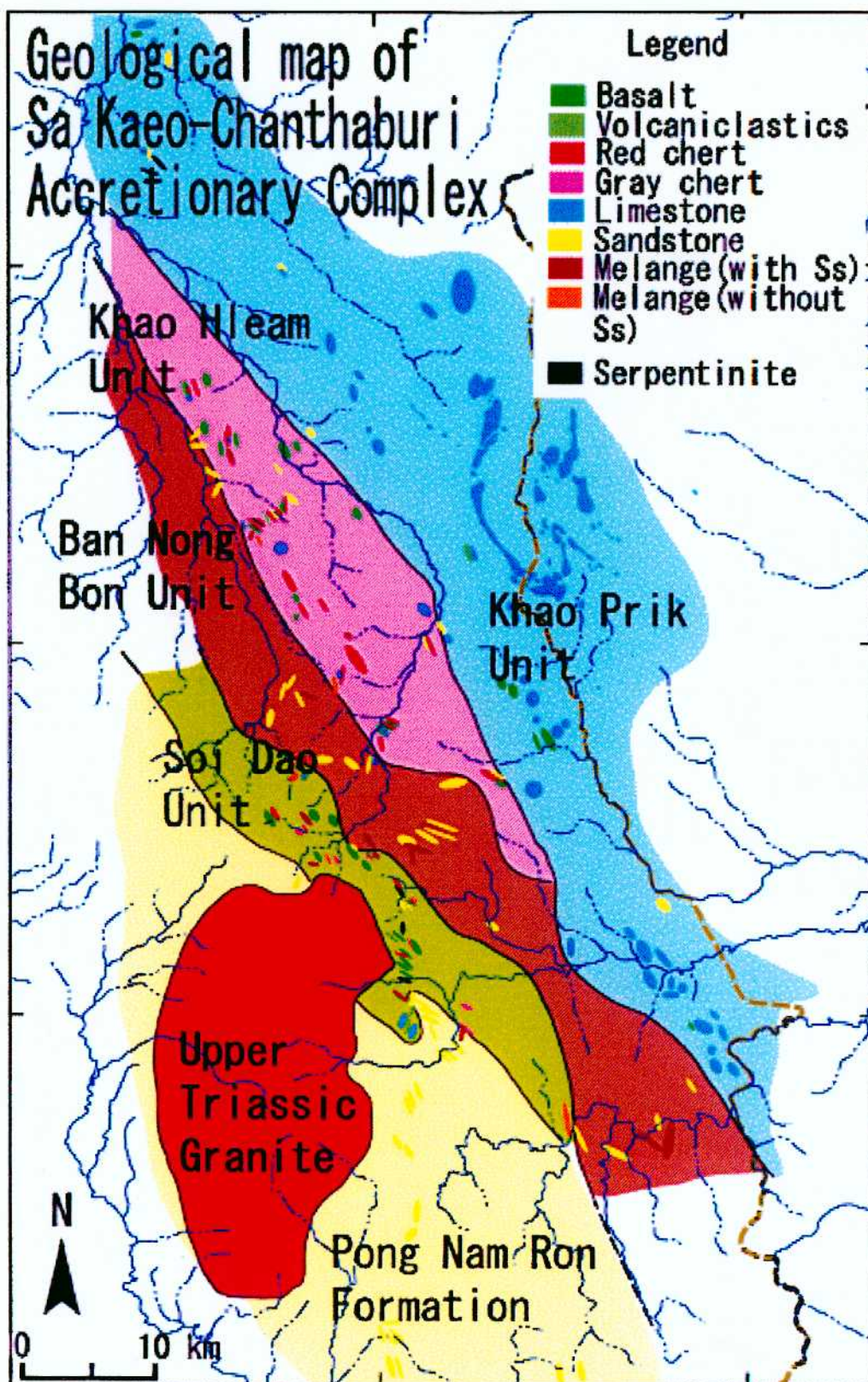


Fig. 9 Geological map of the Sa Kaeo-Chanthaburi accretionary complex.

Table 1 Tectono-stratigraphic units in the Sa Kaeo-Chanthaburi accretionary complex, eastern Thailand

AGE	SA KAEO-CHANTHABURI ACCRETIONARY COMPLEX
QUATERNARY	Q
Middle TRIASSIC	Pong Nam Ron Formation
Lower TRIASSIC Uppermost PERMIAN	<ul style="list-style-type: none"> • Ban Nong Bon Unit • Khao Prik Unit • Khao Hleam Unit • Soi Dao Unit

- (3) Ban Nong Bon unit;
- (4) Soi Dao unit; and
- (5) Pong Nam Ron Formation

2.2.1 Khao Prik Unit

The northernmost unit in the SKCB-AC is that of the Khao Prik unit, which was proposed after the name of one limestone mountain in this unit distributional area. The typical characteristic of this unit is to include huge limestone blocks, which are exposed near the border between Thailand and Cambodia (Plate 1a). These limestone blocks show typical karst topography. Limestones in this unit are generally fossiliferous. The fusulinacean fossils in the Khao Prik unit indicate Middle to Upper Permian.

These limestones are frequently exposed near outcrops of basaltic pillow lava, volcanoclastic rocks and serpentinite, especially in the northern part of the Khao Prik unit distributional area. Clastic sedimentary rocks such as sandstone and shale are also discovered in this unit. Probably the Khao Prik unit is *mélange*, though it is not evident like other units. Except limestone mountains, the unit is generally highly-weathered and is covered by thick soils. It is very difficult to search for good exposure of *mélange*. However, the presence of serpentinite reasonably seems to be a result of *mélange* process in the Khao Prik unit.

The biggest serpentinite body (Plate 1b) in the SKCB-AC is located in the northern part of this Khao Prik unit distributional area. An

alignment of serpentinite bodies distributed in this area is approximately NW-SE trending.

2.2.2 Khao Hleam Unit

The second unit is the Khao Hleam unit, which was named (Chutakositkanon et al., 2001a, 2002, 2003a, 2003b) after the type locality located in the Khao Hleam mountains, that is exposed on the southwest of the Khao Prik unit. The Khao Hleam unit is composed mainly of reddish brown chert, basaltic pillow lava, volcanoclastic rocks with subordinate hyaloclastite, limestone, and serpentinite.

This unit exhibits typical characteristics of *mélange* such as highly faulted, sheared and deformed structures with blocks in shale matrix in several localities (Fig. 10). Basalt, chert and limestone are dominant rock types of blocks, but sandstone, conglomerate and sometime metamorphic rocks also occur as tectonic blocks. Blocks of granitic rock were also reported in previous studies of Hada et al. (1997, 1999).

The basalts in the Khao Hleam unit are dark greenish gray to black porphyry to aphanite. The basaltic rocks usually present pillow lava structure (Figs. 11, 12, 13, 14 and 15; Plates 2 and 3a). Volcanoclastic rocks associated with basaltic pillow lavas of the Khao Hleam unit consist exclusively of clasts of basaltic rocks with some of small limestone and fusulinid fragments (Fig. 16; Plate 3b). It is notable to report that these volcanoclastic rocks carry abundantly detrital chromian spinels in matrix.

UTM 48P 0193671,1475295
 N 13°19'49.5" E 102°10'19.4"
 Highway 317, km 90+210

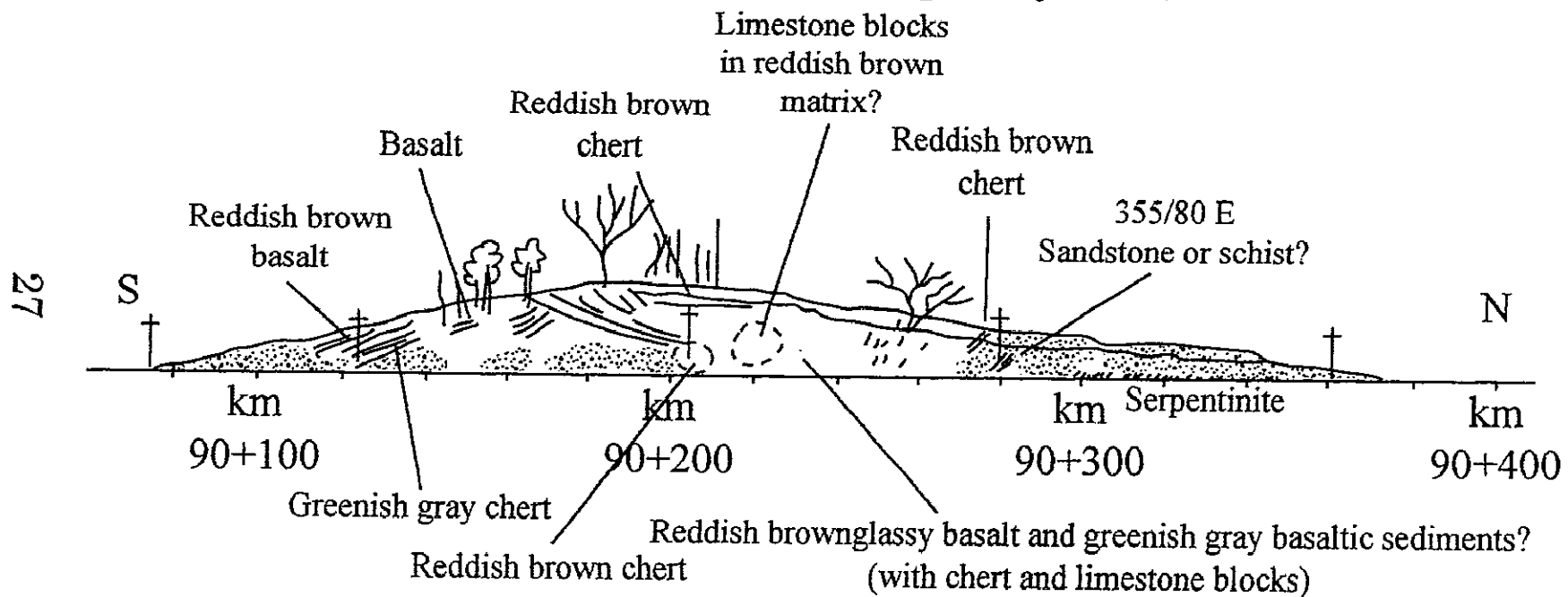


Fig. 10 Outcrop sketch of mélangé in the Khao Hleam units displaying a diverse assemblage of rocks of various sizes with the chaotic structures.

UTM 48P 0193988,1475676
N 13°20'01.8" E 102°10'29.3"
Highway 317, km 90

Basaltic pillow lava

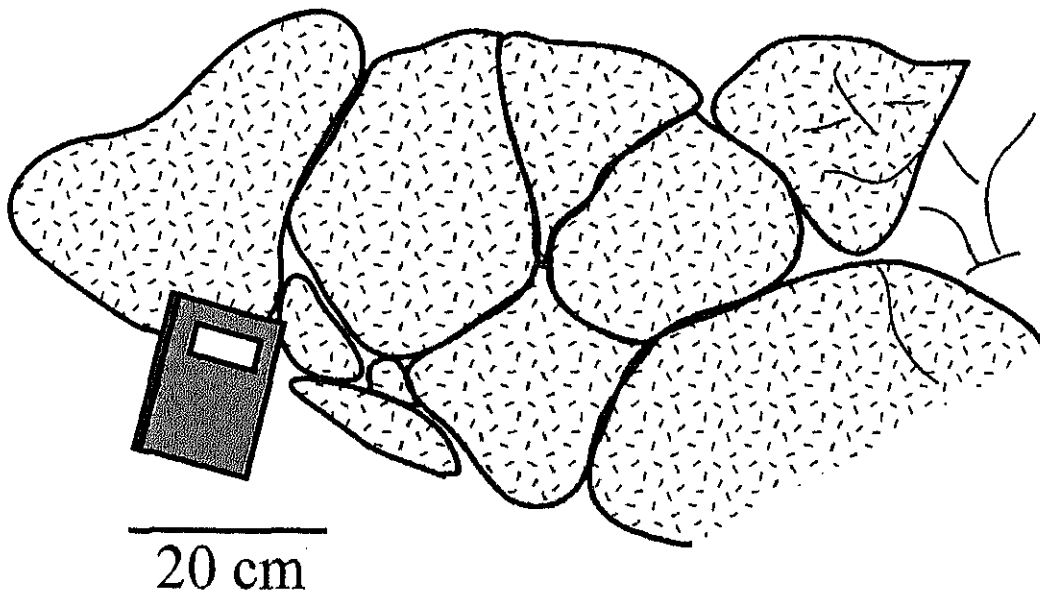
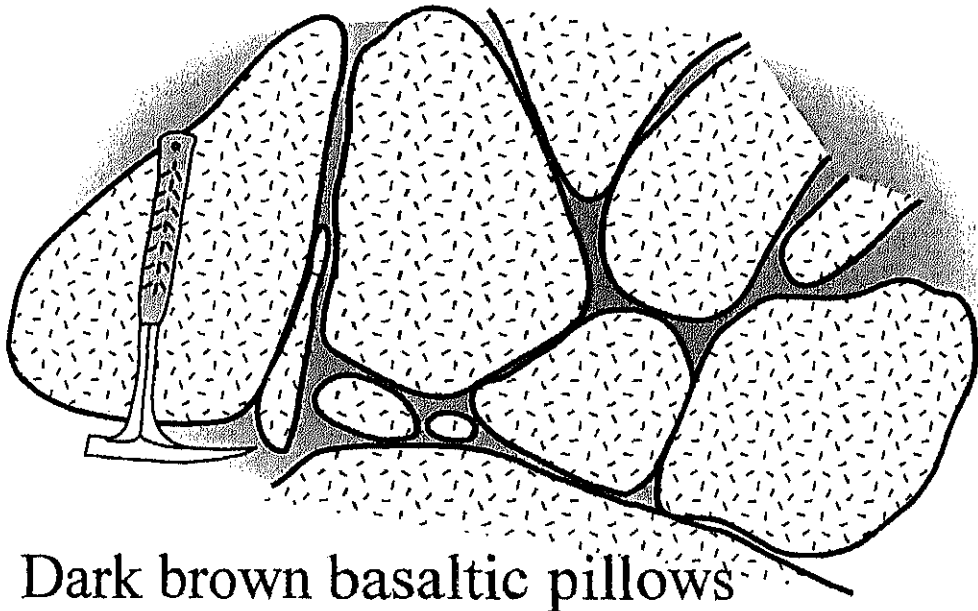


Fig. 11 Outcrop sketch of basalts along the Highway 317 (km 90) in the Khao Hleam unit showing the typical pillow structure. Field note in sketch is a scale.

UTM 48P 0193968,1475685
N 13°20'02.0" E 102°10'28.8"
Highway 317, km 90+700

Green inter-pillows



Dark brown basaltic pillows

Fig. 12 Outcrop sketch of dark brown basalts along the Highway 317 (km 90+700) in the Khao Hleam unit showing the characteristics of pillow structures with green inter-pillows. Hammer in sketch is a scale.

UTM 48P 0193238,1474918
 N 13°19'36.8" E 102°10'04.8"
 Wat Khao Hleam

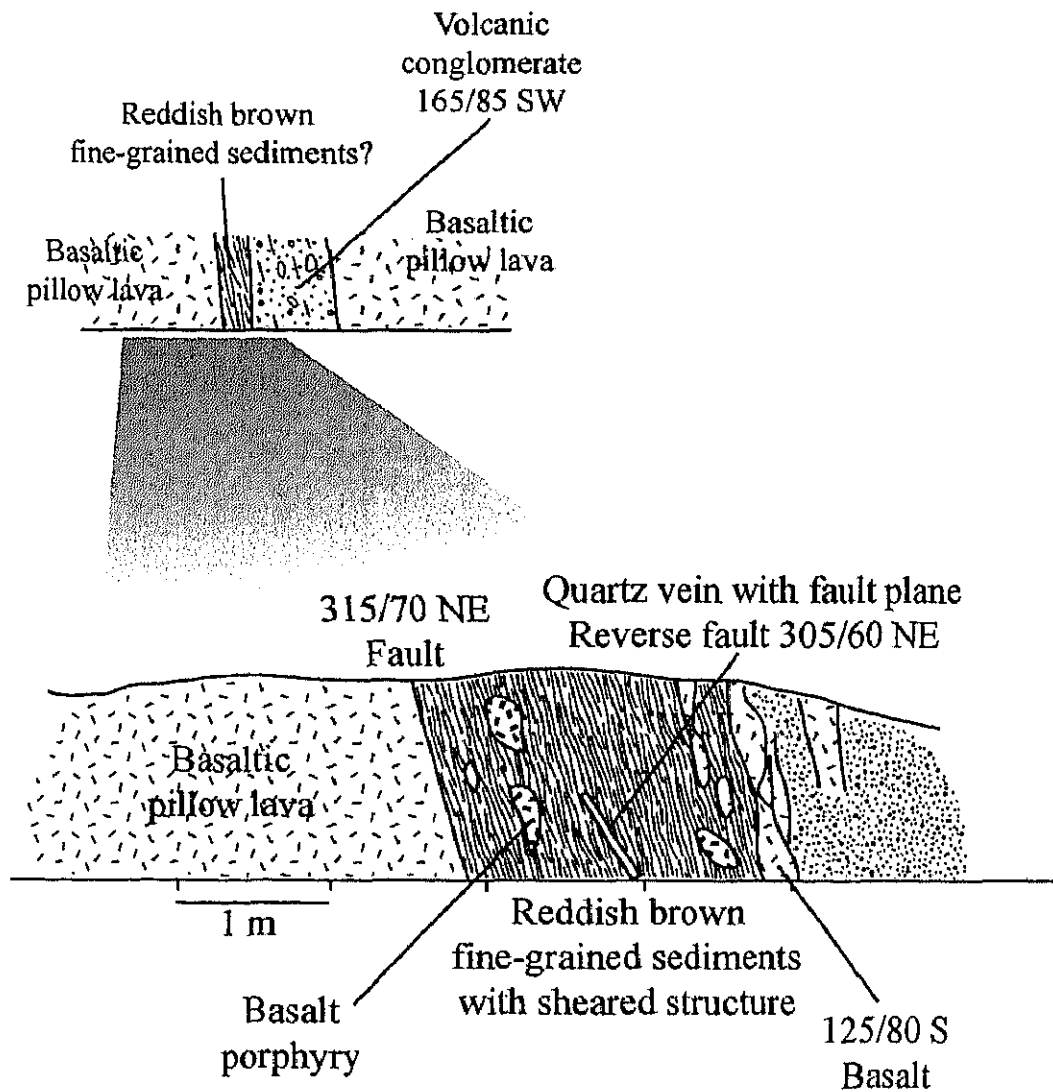


Fig. 13 Outcrop sketch of basaltic pillow lavas associated with fault contacts at Wat Khao Hleam in the Khao Hleam unit.

UTM 48P 0193285,1474941
N 13°19'37.3" E 102°10'06.5"
Wat Khao Hleam

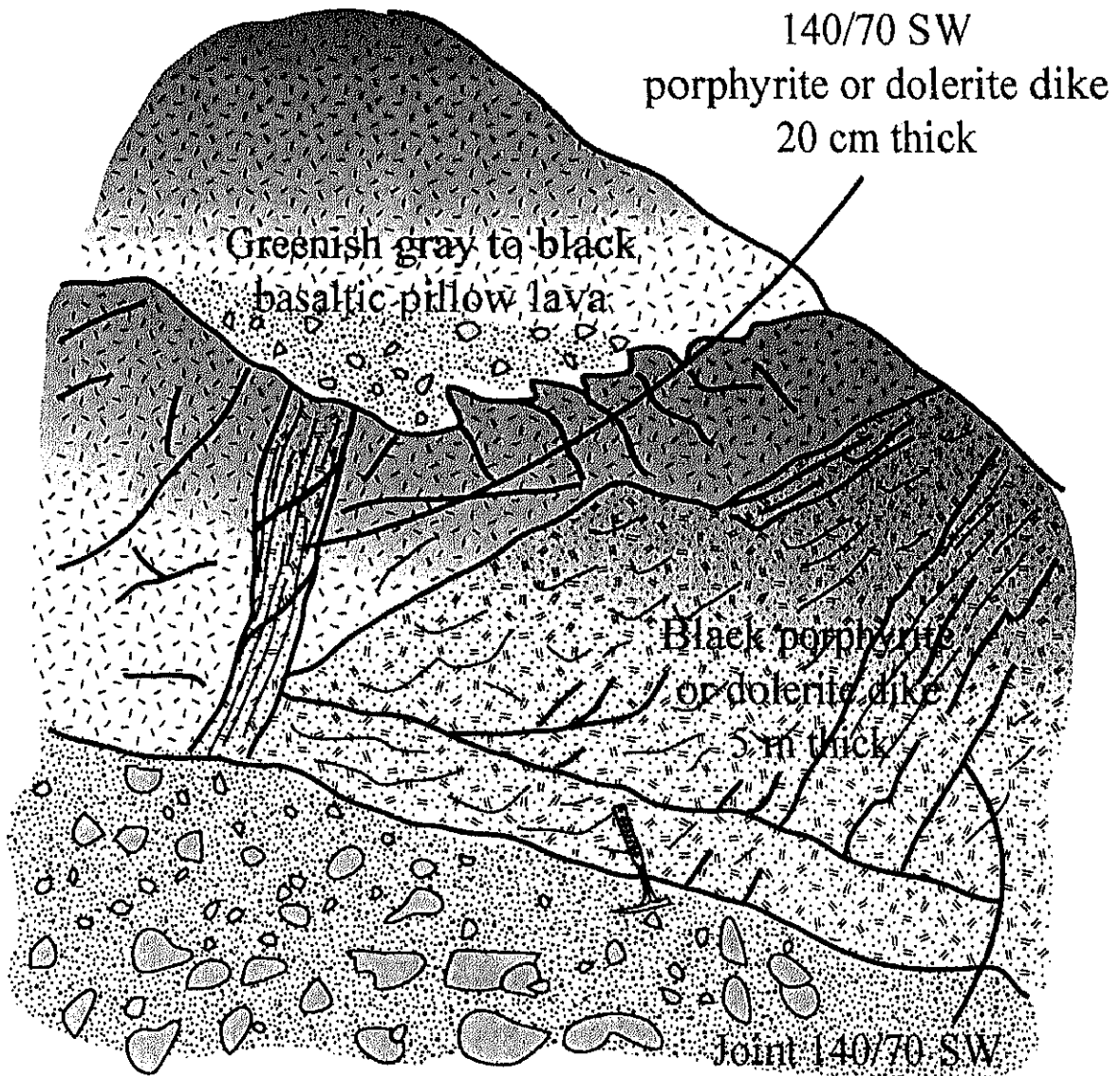


Fig. 14 Outcrop sketch of basaltic pillow lavas intruded by black porphyrite or dolerite dikes at the same location as Fig. 13. Hammer in sketch is a scale.

UTM 48P 0193301,1474336
N 13°19'17.9" E 102°10'07.4"
Highway 317, km 89+150

Greenish gray to black
sheared basalts
with small blocks of
greenish gray cherts
and sandstones

Zone of
reddish brown
chert floats

Reverse fault 325/80 NE
= Block moved to SW

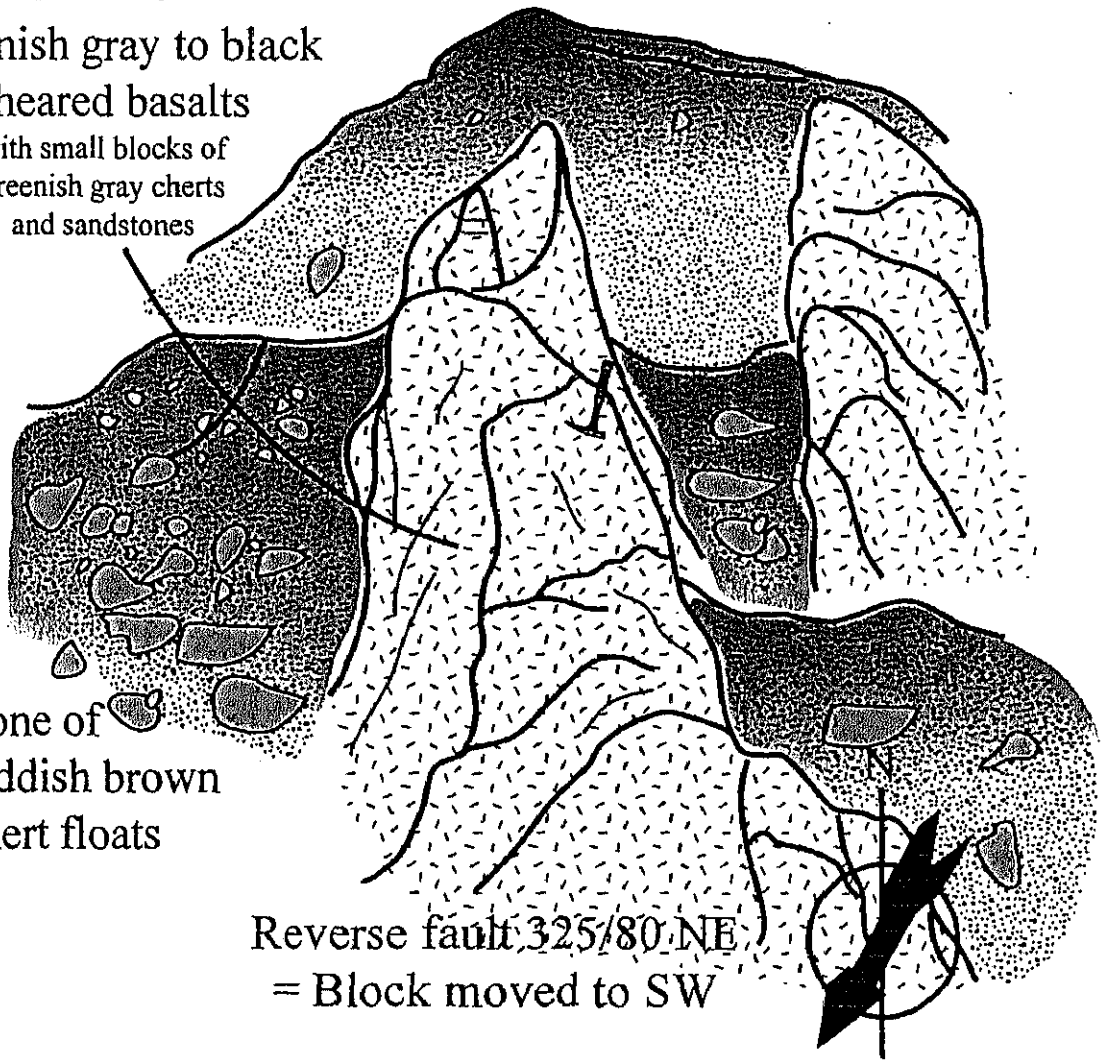


Fig. 15 Outcrop sketch of tectonically deformed basalt rocks associated with reddish brown chert floats. Small blocks of greenish gray chert and sandstone are found in the deformed basalts.

UTM 48P 0194035,1475742
N 13°20'03.9" E 102°10'31.3"
Highway 317, km 90+790

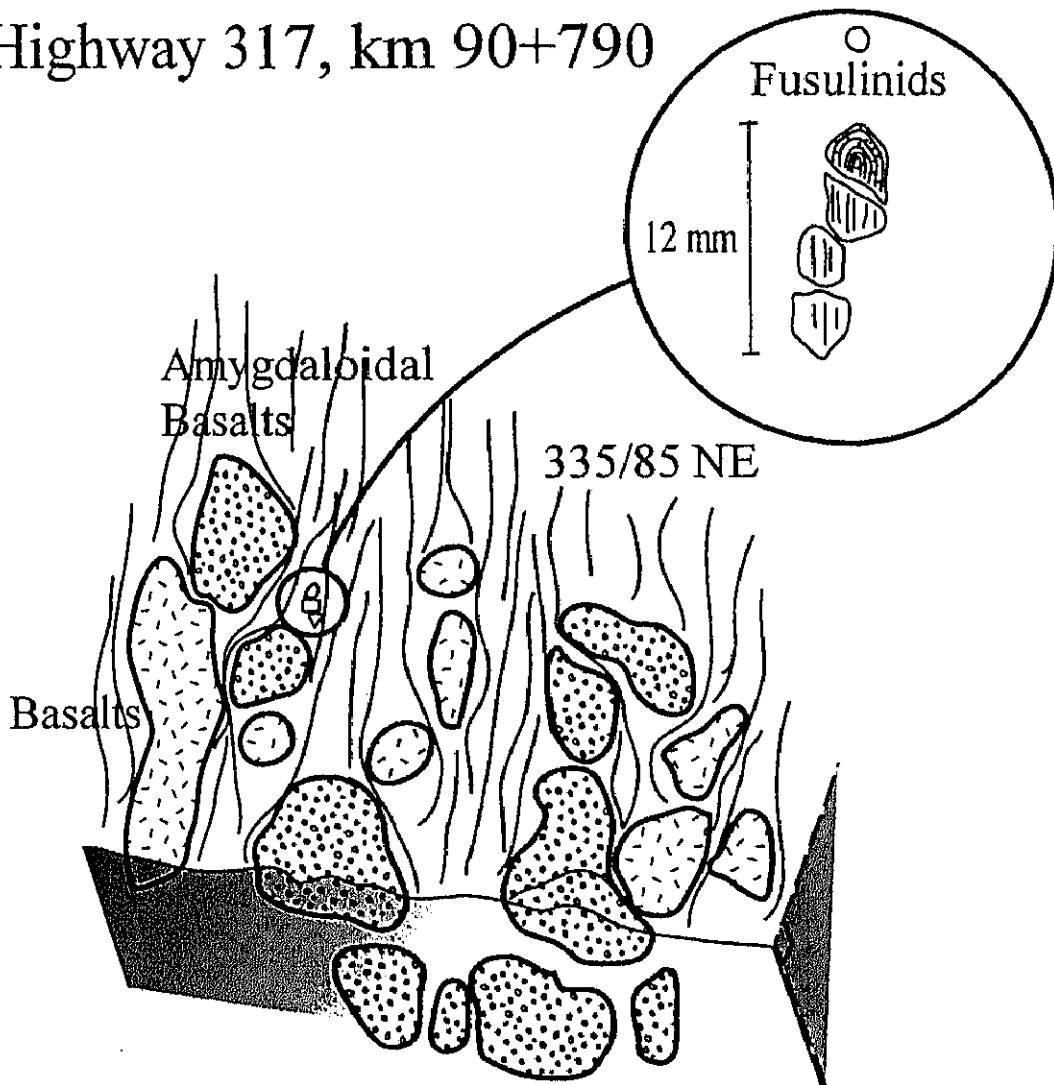


Fig. 16 Outcrop sketch of volcaniclastic rocks associated with pillow lavas (Figs. 11 and 12) showing clasts of amygdaloidal basalts and porphyritic basalts. Some fusulinids are found in matrix part of volcaniclastic rock.

Radiolarians are rather abundant in reddish brown cherts of the Khao Hleam unit. They can be discovered from bedded cherts in large hill sized blocks and small blocks or tiny clasts in *mélange* (Figs. 17 and 18; Plate 4). According to the previous reports (Sashida et al., 1997; Hada et al., 1997), Early to Late Permian radiolarians are discriminated from these reddish brown cherts of the Khao Hleam unit.

Limestones occurred as blocks in the Khao Hleam unit are various sizes, ranging from less than a few meters to hill-sized bodies (Fig. 19). Generally they are fossiliferous and contain fusulinacean fossils in several places. These fusulinacean fossils in the Khao Hleam unit indicate Lower to Middle Permian (Fontaine and Salyapongse, 1997; Fontaine et al., 1997; Hada et al., 1997, 1999).

Highly weathered and sheared serpentinites usually occur as small outcrops in *mélange* belt.

2.2.3 Ban Nong Bon Unit

The Ban Nong Bon unit of the SKCB-AC is exposed between the distributional areas of the Khao Hleam and Soi Dao units. In the previous studies (Siwaboworn et al., 1976; Salyapongse, 1992; Chaodumrong, 1992b; Hada et al., 1997, 1999), the Ban Nong Bon unit had been was recognized as a part of the Pong Nam Ron Formation. Recently, its *mélange* characteristics (Figs. 20, 21 and 22) are discovered in the field investigation. It is newly named after the name of “Ban Nong Bon village” where type locality is proposed (Chutakositkanon et al.,

UTM 48P 0199176,1463629
N 13°13'31.7" E 102°13'26.4"
Highway 3448, km 6+850

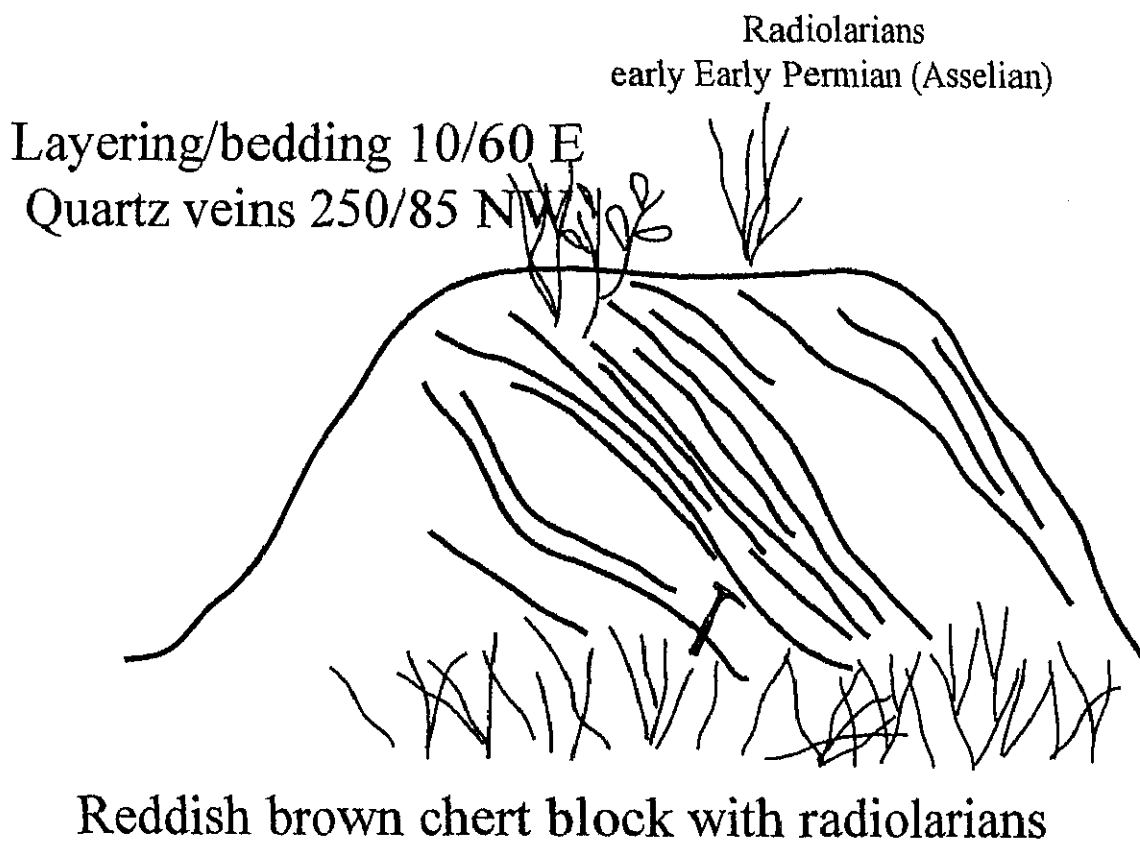


Fig. 17 Outcrop sketch of reddish brown radiolarian-bearing bedded cherts along the Highway 3448 (km 6+850) showing large size of a block in mélange of the Khao Hleam unit.

UTM 48P 0195274,1477431
N 13°20'59.4" E 102°11'11.6"

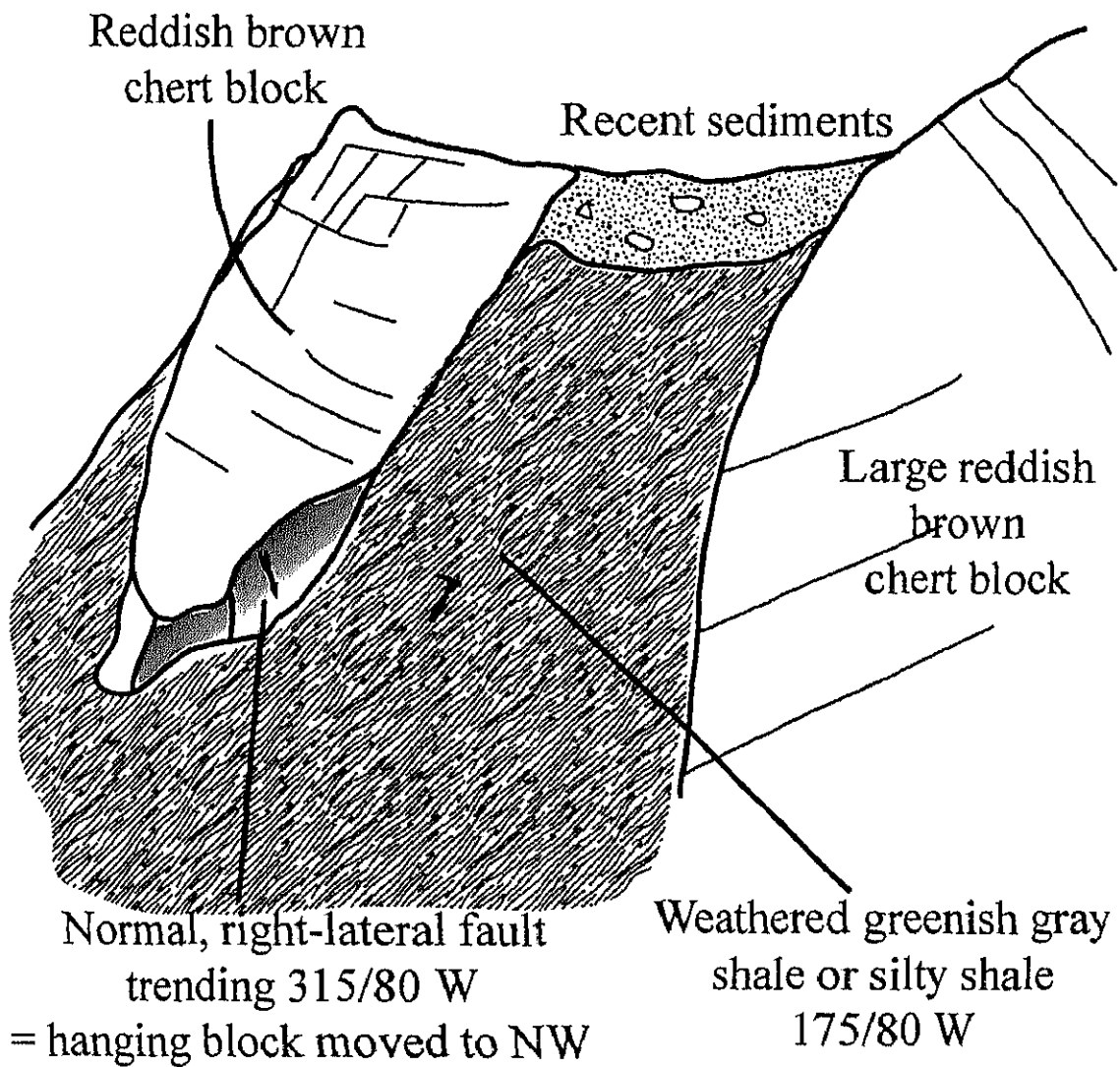


Fig. 18 Outcrop sketch of large blocks of reddish brown chert in shale matrix near the radiolarian location in the Khao Hleam unit. Hammer in sketch is a scale.

UTM 48P 0194723,1476235
N 13°20'20.3" E 102°10'53.8"
Highway 317, km 91+600

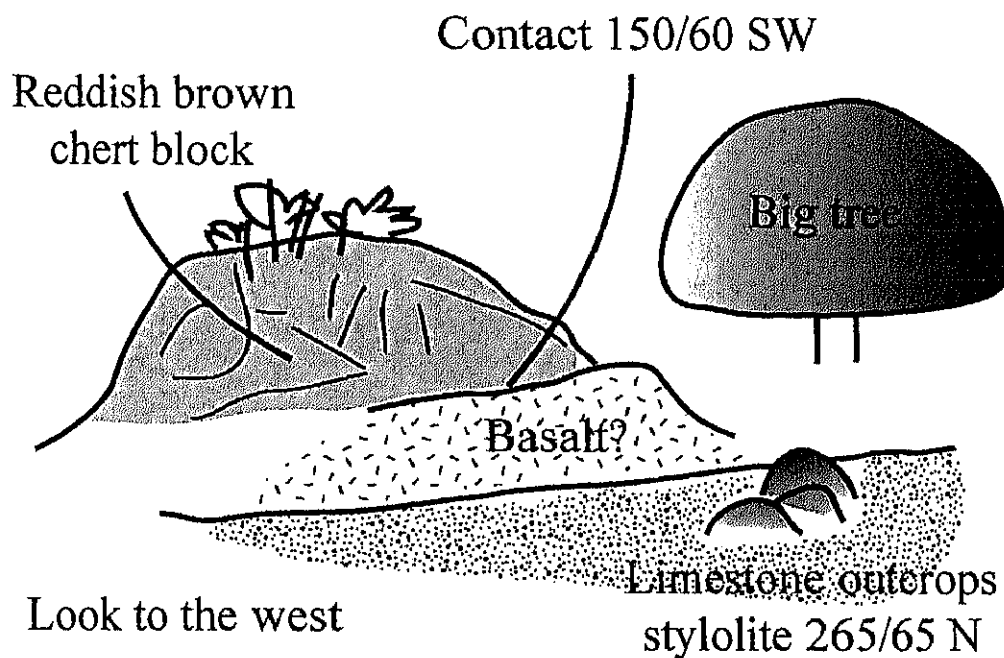


Fig. 19 Outcrop sketch of reddish brown chert, basalt and limestone near the Highway 317 (km 91+600) in the Khao Hleam unit showing their relationship among each other. Tree (6 m high) in sketch is a scale.

UTM 48P 0222852,1429298
N 12°55'03.6" E 102°26'43.7"
Highway 3193, km 21+200

38

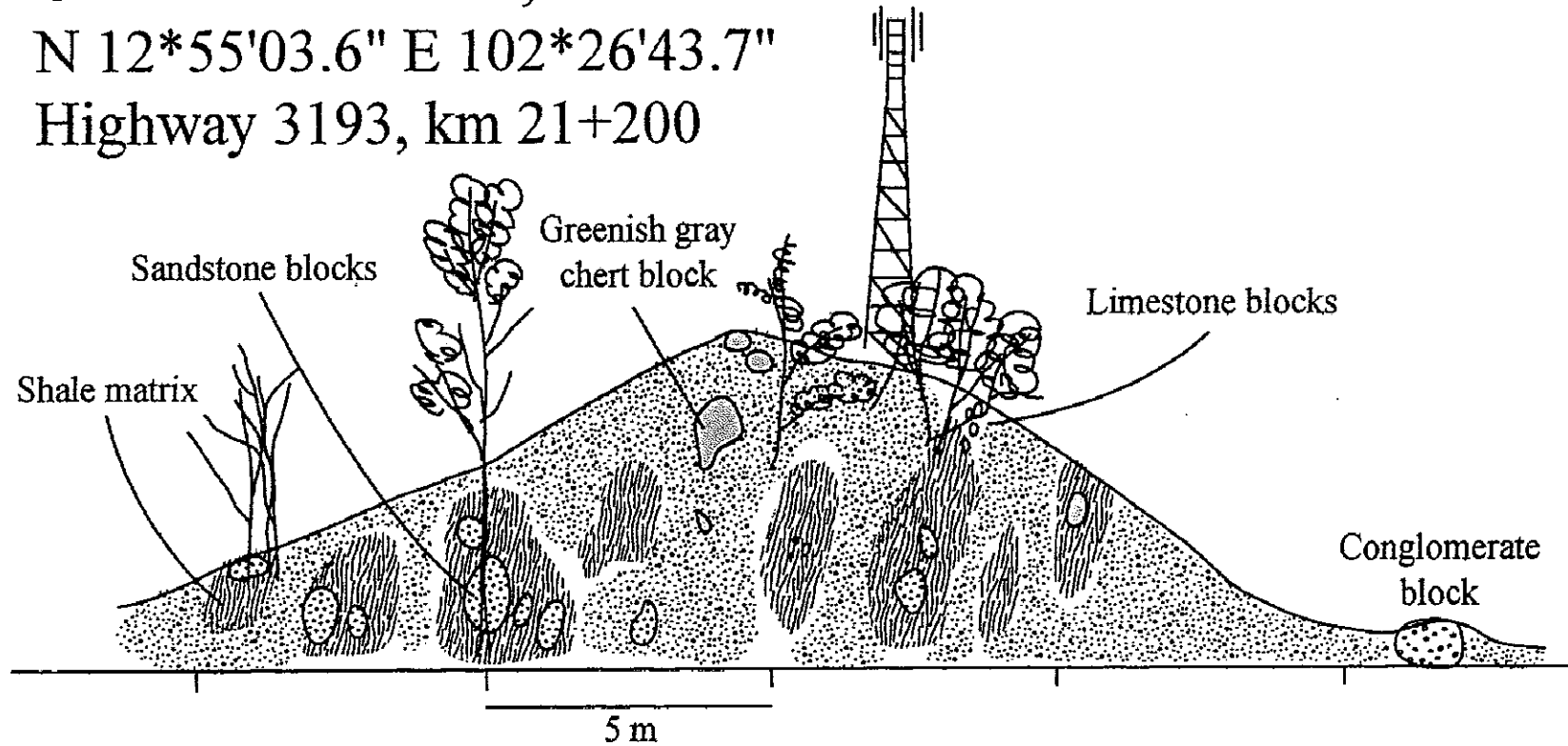
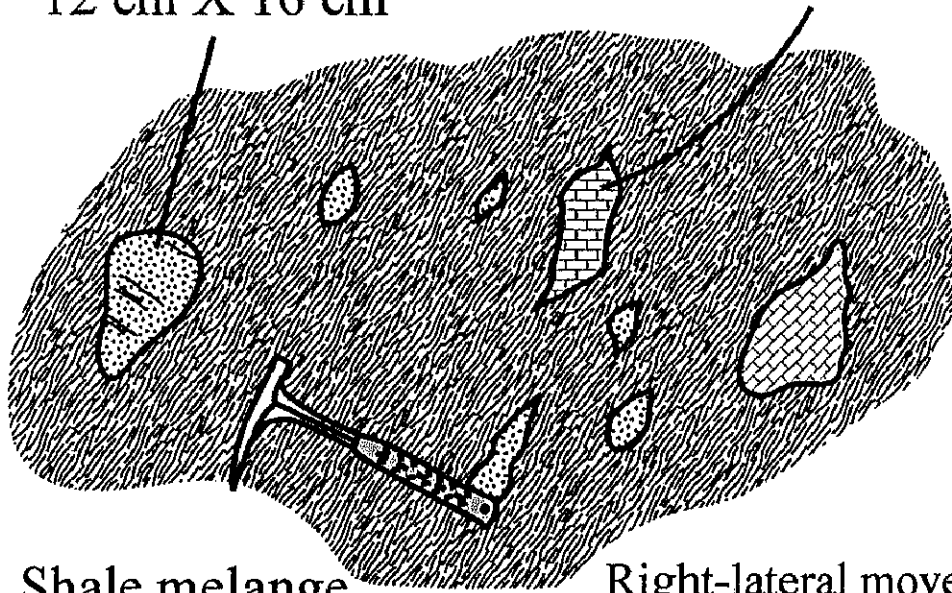


Fig. 20 Outcrop sketch of mélangé at type locality of the Ban Nong Bon unit showing the distributions of sandstone, gray chert, limestone and conglomerate blocks in shale matrix.

UTM 48P 0222849,1429320
 N 12°55'04.2" E 102°26'43.6"
 Highway 3193, km 21+200

Sandstone block
 12 cm X 16 cm

Limestone block
 6 cm X 15 cm



Shale melange
 190/90 E

Right-lateral movement

Blocks :- sandstone, chert,
 limestone, conglomerate

Max. size of blocks
 = 1 m X 2 m of sandstone
 and chert blocks

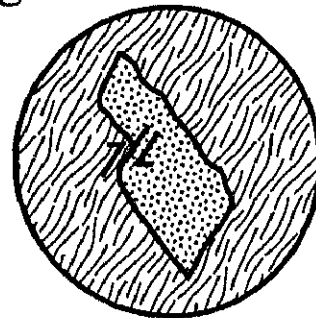


Fig. 21 Outcrop sketch of mélangé at the same location as Fig. 20 showing alignment of blocks of sandstones and limestones.

UTM 48P 0222849,1429320
N 12°55'04.2" E 102°26'43.6"
Highway 3193, km 21+200

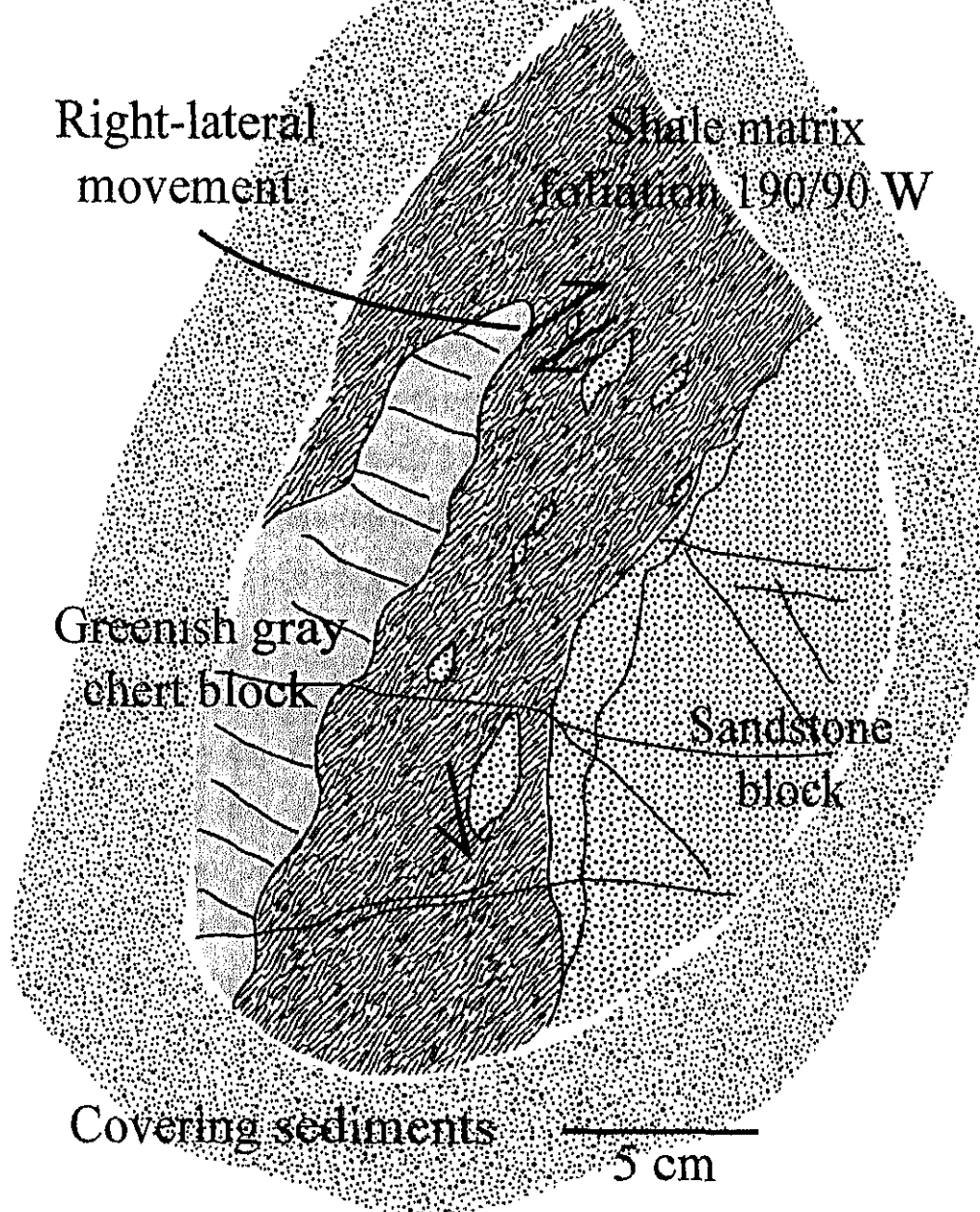


Fig. 22 Outcrop sketch of close-up on surface of mélangé rock at the same location as Fig. 20 displaying the major foliation and slip sense of chert and sandstone blocks.

2001a, 2002, 2003a, 2003b).

Shale mélanges can be recognized in several places in the Bon Nong Bon unit (Plate 5). These mélange characteristics are a critical key to discriminate the Bon Nong Bon unit from the turbiditic sandstone and shale alternations of the Pong Nam Ron Formation. Mélange, broken formation and coherent turbidite sequence of the Ban Nong Bon unit comprise mainly sandstone and shale (Figs. 23 and 24). Sandstone and conglomerate are the dominant rock types of blocks of the Ban Nong Bon unit. Chert and limestone also occur as small tectonic blocks in shale matrix, ranging from a few centimeters to a few meters in diameter. Sandstone and shale alternations in the broken and coherent formations of the Bon Nong Bon unit generally display characteristics of turbidite (Fig. 25). These clastic rocks are very strongly weathered.

Conglomerates in the Ban Nong Bon unit are distributed in several places. They can form as outcrop sized mélange blocks (Fig. 26) in shale matrix or hill sized exposures. Conglomerates of hill-sized exposures at Khao Sa Taeng are composed of various kinds of well-rounded rock clasts (ranging from one cm to 15 cm in diameter) in sandstone matrix (Fig. 27). Almost lithic clasts are various colored chert, quartz, porphyritic to aphanitic volcanic rocks, fine- to medium-grained plutonic rock, metamorphic rock and limestone. The matrix is greenish gray in color. On the other hand, finer grained conglomerate blocks in shale mélange in the type locality to south of Ban Nong Bon comprise mainly various colored chert, basaltic volcanic rocks and limestone with subordinate sandstone and shale (Plate 6).

UTM 48P 0204852,1451132
 N 13°06'47.7" E 102°16'39.3"
 Highway 3424, km 3+800

Deformed
 sandstones and shales
 bedding? 350/45 E

Blocks of sandstone, chert
 and limestone on top

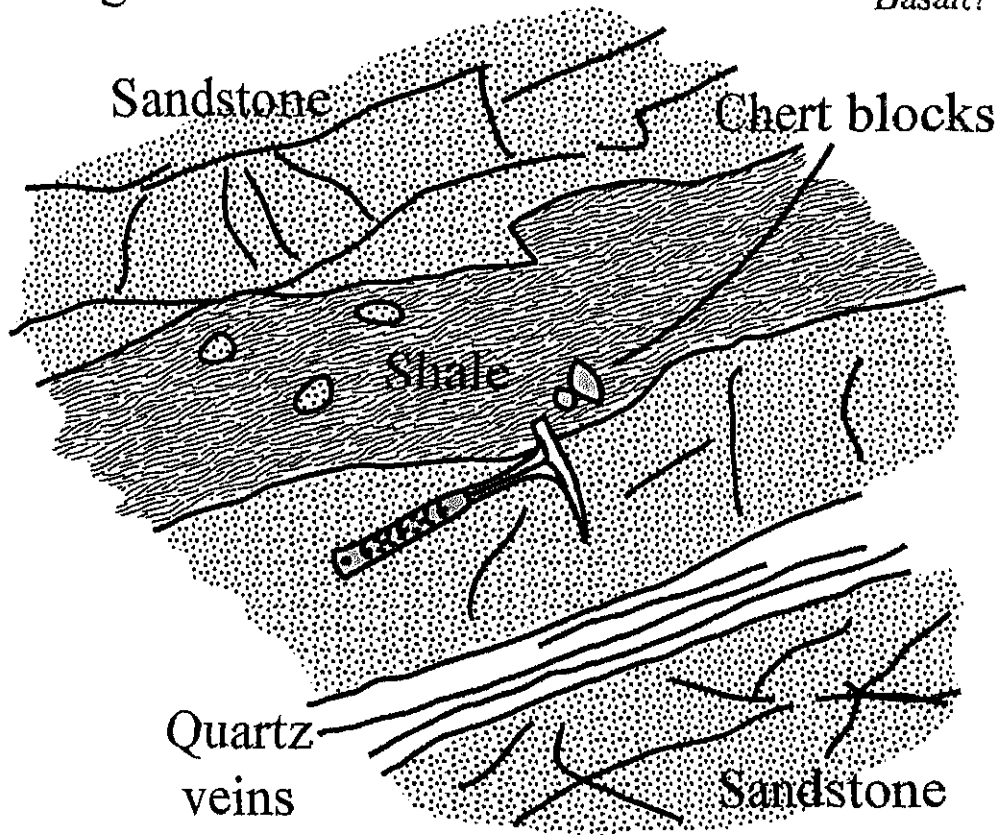
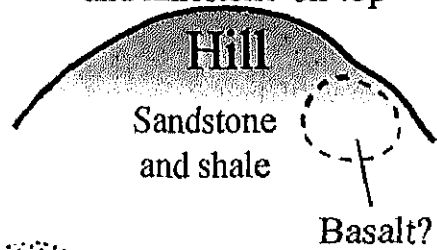


Fig. 23 Outcrop sketch of mélangé along the Highway 3424 (km 3+800) in the Ban Nong Bon unit showing various sizes of sandstone blocks in shale matrix. Hammer in sketch is a scale.

UTM 48P 0196707,1463228
N 13°13'18.3" E 102°12'05.0"
Highway 3448

Sandstone

Bedding plane 290/80 N

Shear plane of
duplex structures
290/65 N

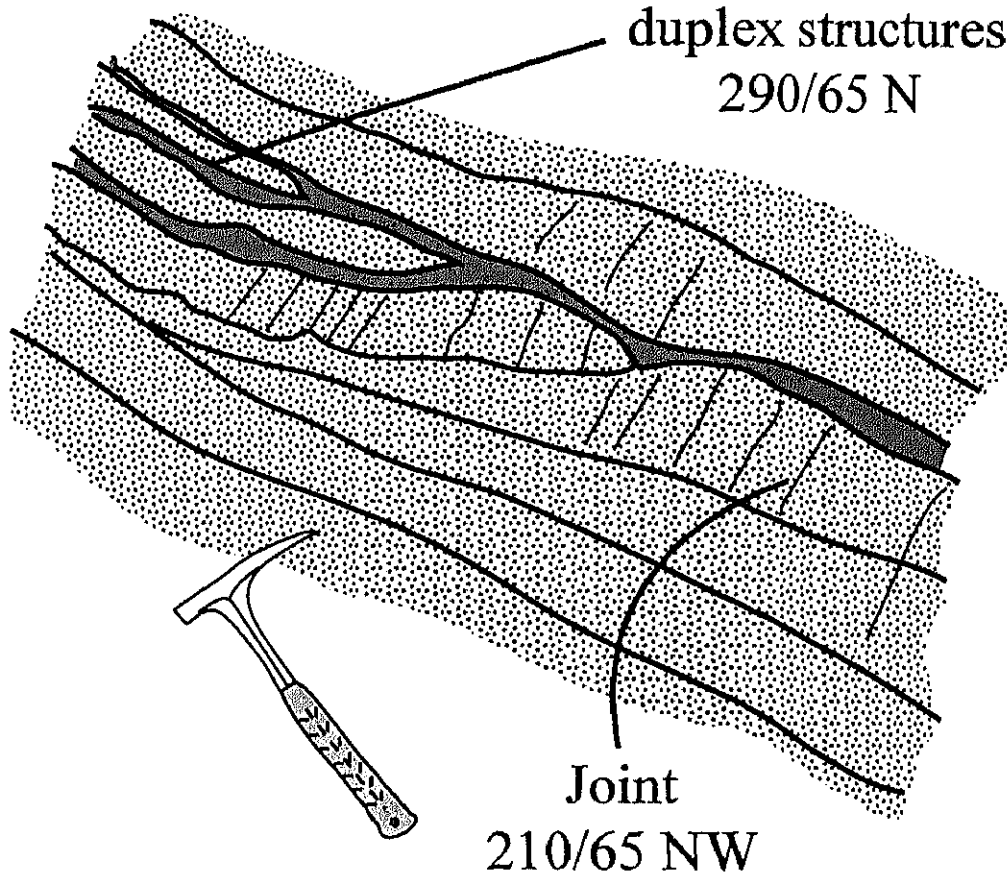


Fig. 24 Outcrop sketch of duplex developed in sandstone beds of coherent turbidite sequence in the Ban Nong Bon unit along the Highway 3448. Hammer in sketch is a scale.

UTM 48P 0194029,1461213
N 13°12'11.5" E 102°10'36.5"
Highway 317, km 74+390

Large block of a turbiditic sequence in melange

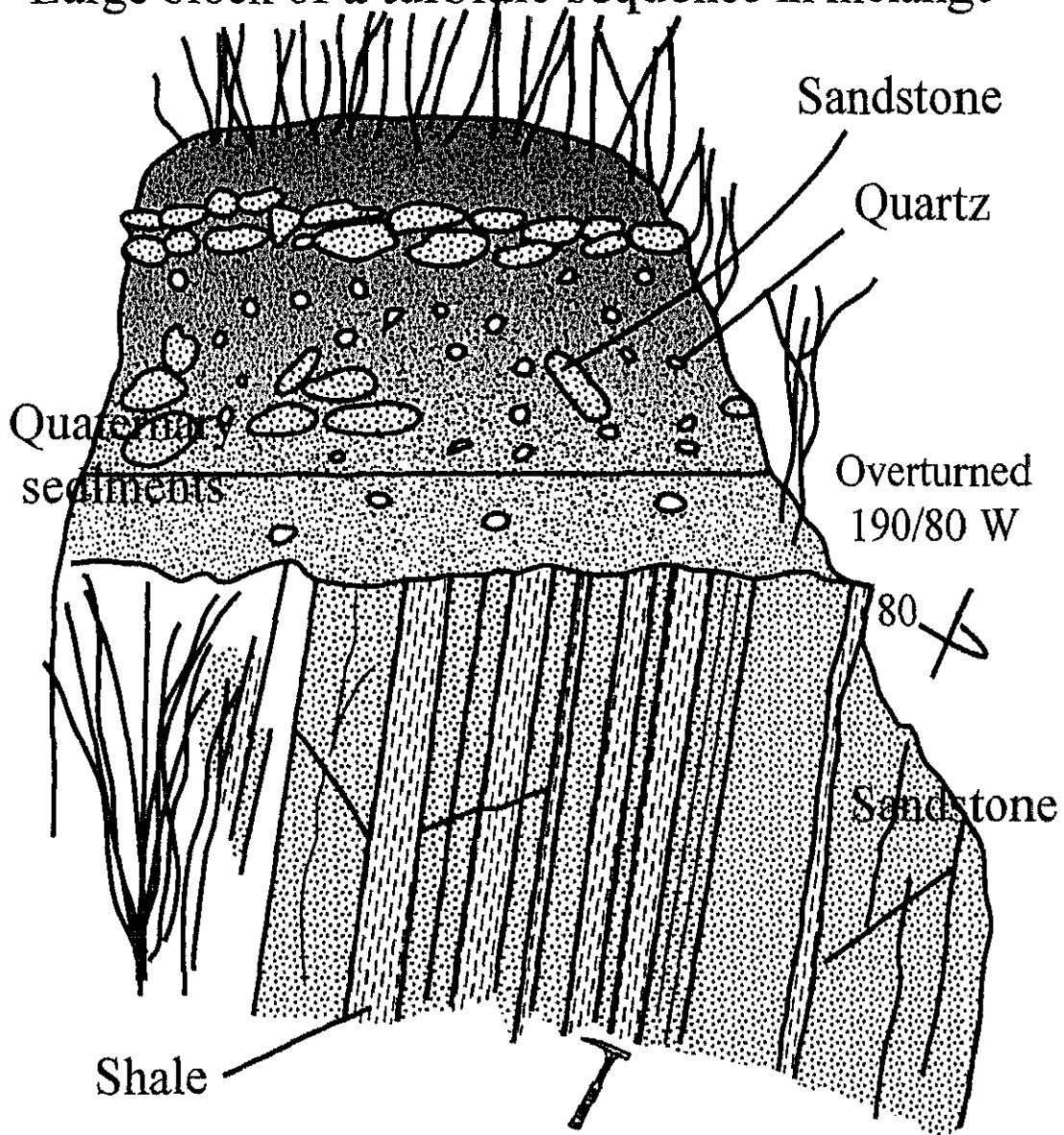


Fig. 25 Outcrop sketch of the turbidite sequence in the Ban Nong Bon unit along the Highway 317 (km 74+390) showing alternation of sandstone and shale. It is covered by Quaternary sediments. Hammer in sketch is a scale.

UTM 48P 0195602,1464730
N 13°14'06.5" E 102°11'26.7"
Highway 317, km 78

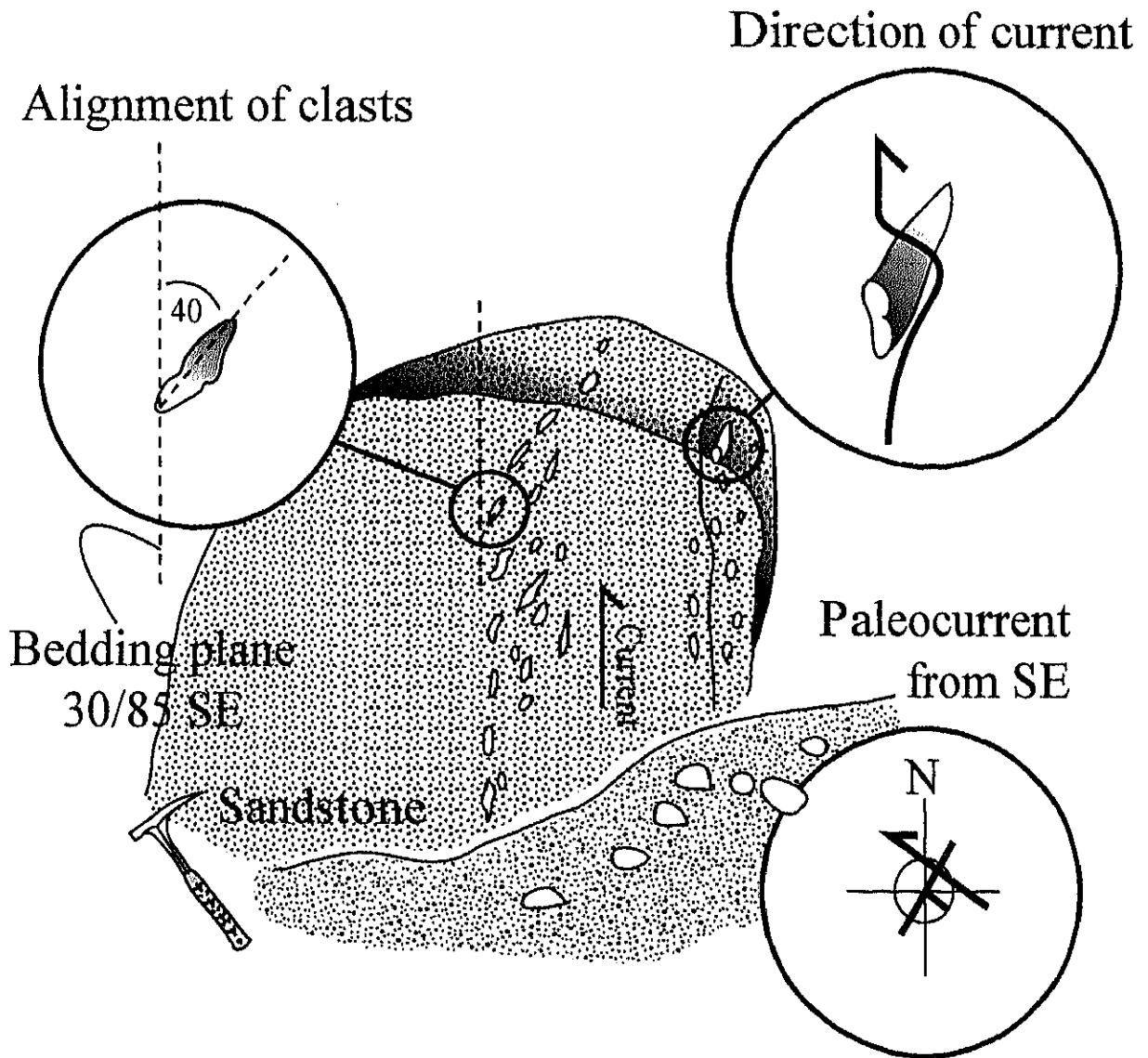


Fig. 26 Outcrop sketch of the conglomerate and sandstone of the coherent succession in the Ban Nong Bon unit. Paleocurrent is measured from the alignment of clast imbrication and is from southeast.

UTM 48P 0204947,1451681
 N 13°07'05.4" E 102°16'42.3"
 Highway 3424, km 4+650

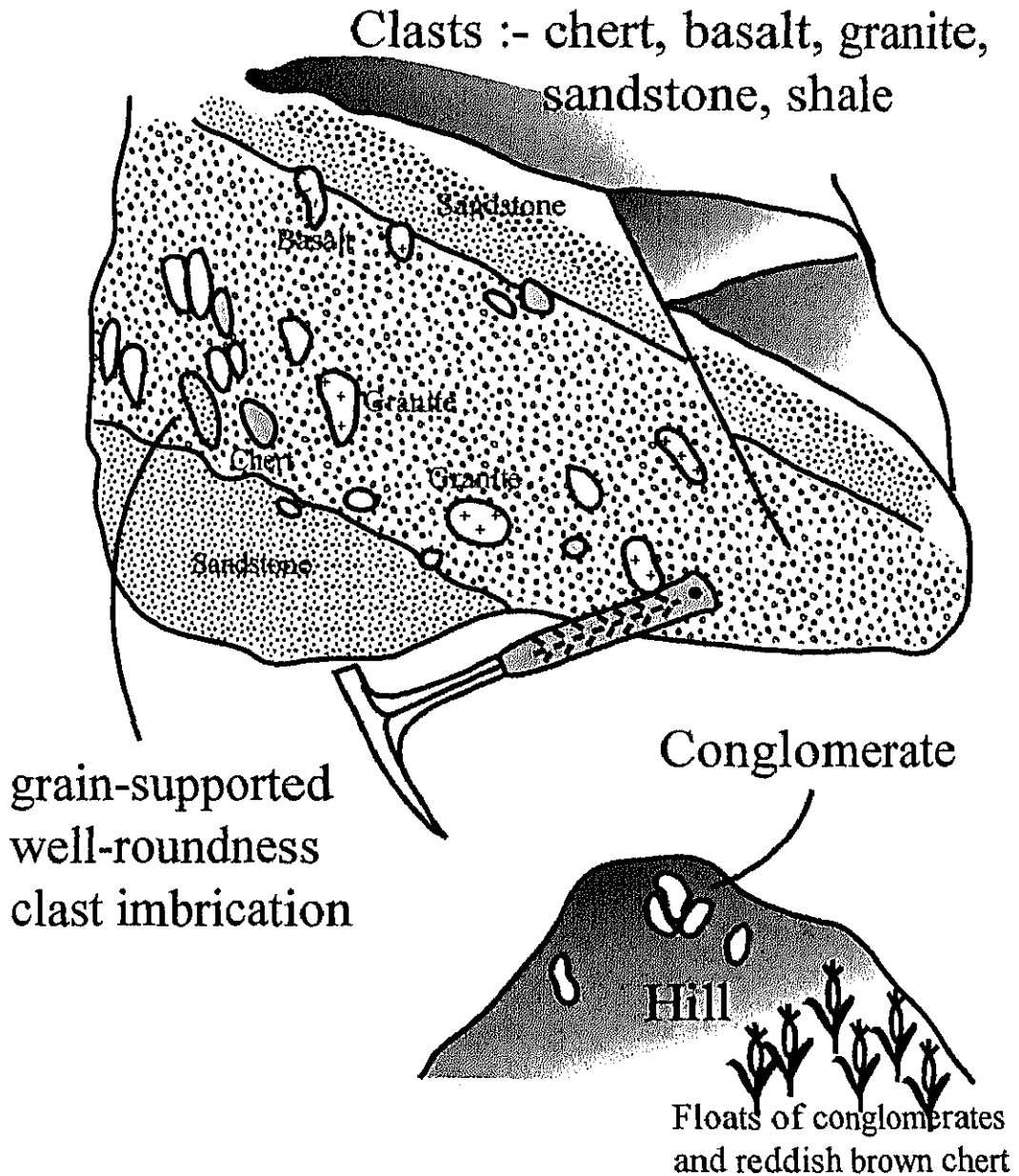


Fig. 27 Outcrop sketch of large “loose” block of conglomerate on the top of the Khao Sa Taeng hill showing various kinds of well-rounded rock clasts in sand matrix. Fine to medium grained granite are also found.

2.2.4 Soi Dao Unit

The Soi Dao unit was proposed following the name of type location, Soi Dao district in the Chanthaburi province (Chutakositkanon et al., 2001a, 2002, 2003a, 2003b). It is exposed on the southwest of the Ban Nong Bon unit. Generally this unit is very similar with the Khao Hleam unit. It is no debate that the Soi Dao unit is mélangé of oceanic plate materials, since this unit displays typical characteristics of mélangé such as high faulted, sheared and deformed structures with blocks in shale matrix. Basalt, chert and limestone are the dominant rock types in this mélangé unit (Figs. 28, 29, 30 and 31; Plate 7). Sandstone also occur as tectonic blocks in shale matrix in several locations (Fig. 32).

Unlike cherts in the Khao Hleam unit, chert blocks and clasts in the Soi Dao unit are usually gray to greenish gray colors. However reddish brown cherts are rarely found in some places (Plate 7b). Radiolarians are recently discovered and identified from gray chert in the southern part of the Soi Dao unit. A find of radiolarian fossils, *Pseudoalbaillella scalplata* m. *rhombothoracata* of *Albaillella sinuate* Zone, indicate middle Early Permian or Sakmarian to Artinskian (Kamata et al., 2003) (Fig. 33).

Fossiliferous limestones occur locally as hill-sized blocks and small blocks in mélangé associated with basalt and chert. They contain abundant fusulinacean fossils in several places. The fusulinacean fossils in the Soi Dao unit indicate lower Middle Permian (Fontaine and Salyapongse, 1997; Fontaine et al., 1997). In some places, greenish gray volcanoclastic rocks, possibly basaltic clast-bearing hyaloclastites, are in

UTM 48P 0198998,1453550
N 13°08'03.5" E 102°13'23.8"
Soi Dao District

Basaltic pillows

Arrows indicate Top
from pillow shape

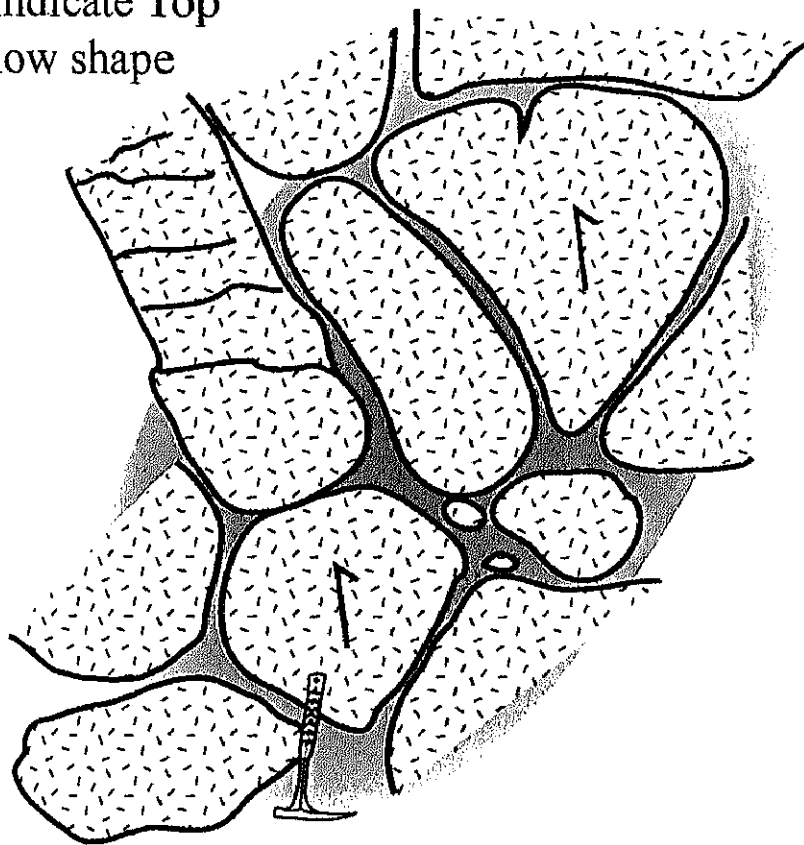


Fig. 28 Outcrop sketch of basalts in the Soi Dao unit showing the typical pillow structure. Arrows indicate top from pillow shape. Hammer in sketch is a scale.

UTM 48P 0215946,1430236
 N 12°55'31.6" E 102°22'54.5"
 Highway 3247, km 1+500

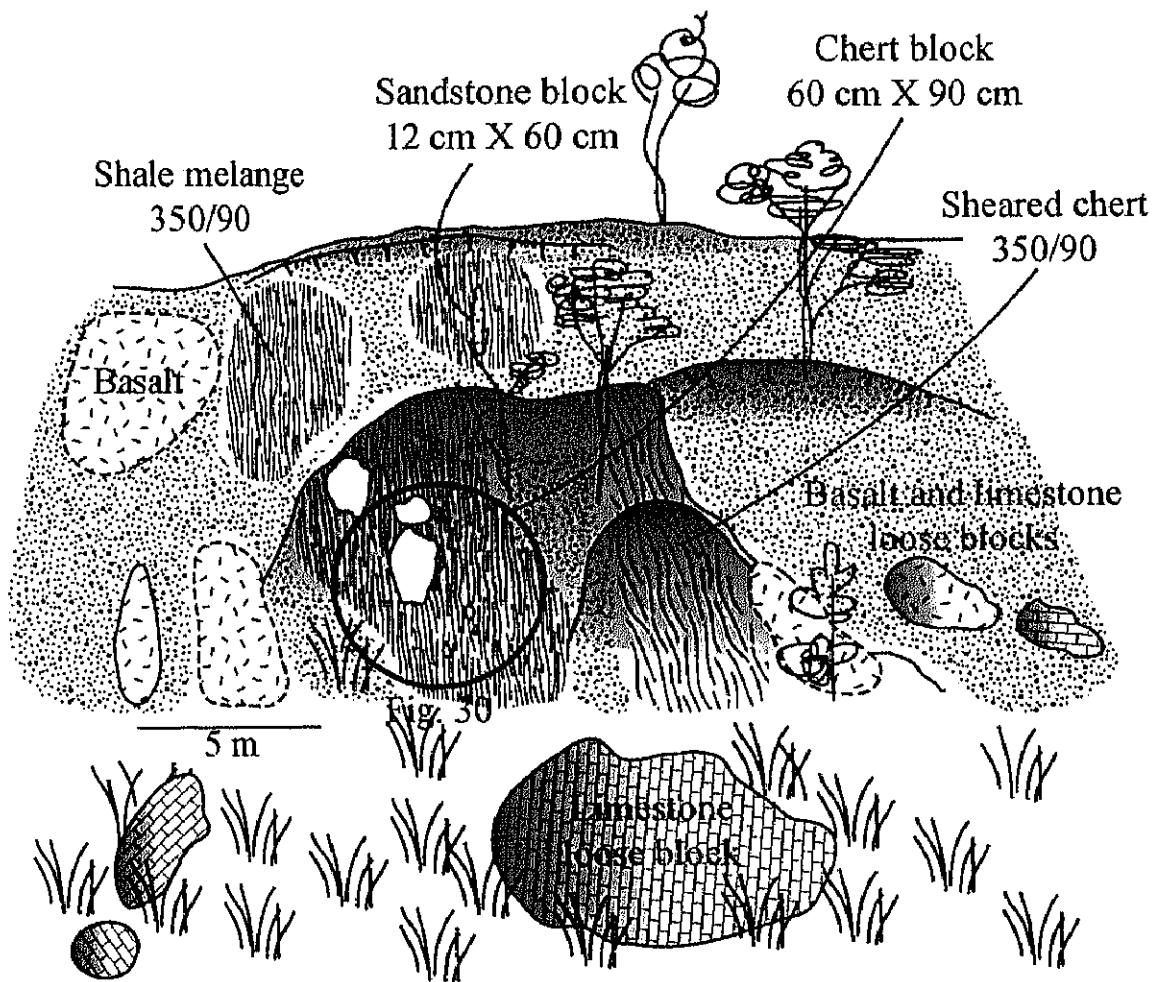


Fig. 29 Outcrop sketch of mélangé of the Soi Dao unit displaying mélangé foliation and their tectonic blocks of greenish gray cherts, basalts and limestones.

UTM 48P 0215946,1430236
N 12°55'31.6" E 102°22'54.5"
Highway 3247, km 1+500

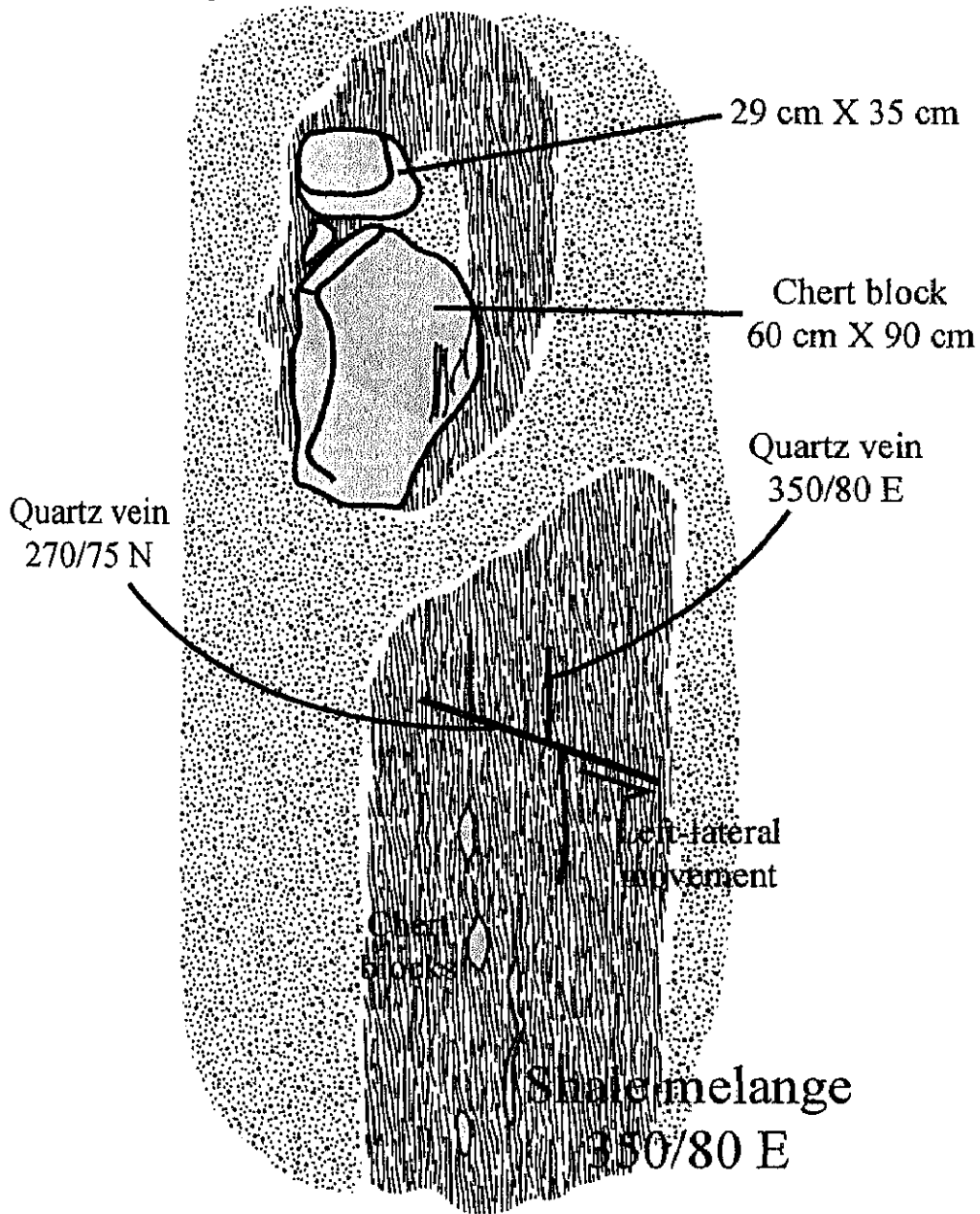


Fig. 30 Outcrop sketch of close-up chert blocks in the same place as Fig. 29, showing various sizes of blocks in matrix.

UTM 48P 0215946,1430236
N 12°55'31.6" E 102°22'54.5"
Highway 3247, km 1+500

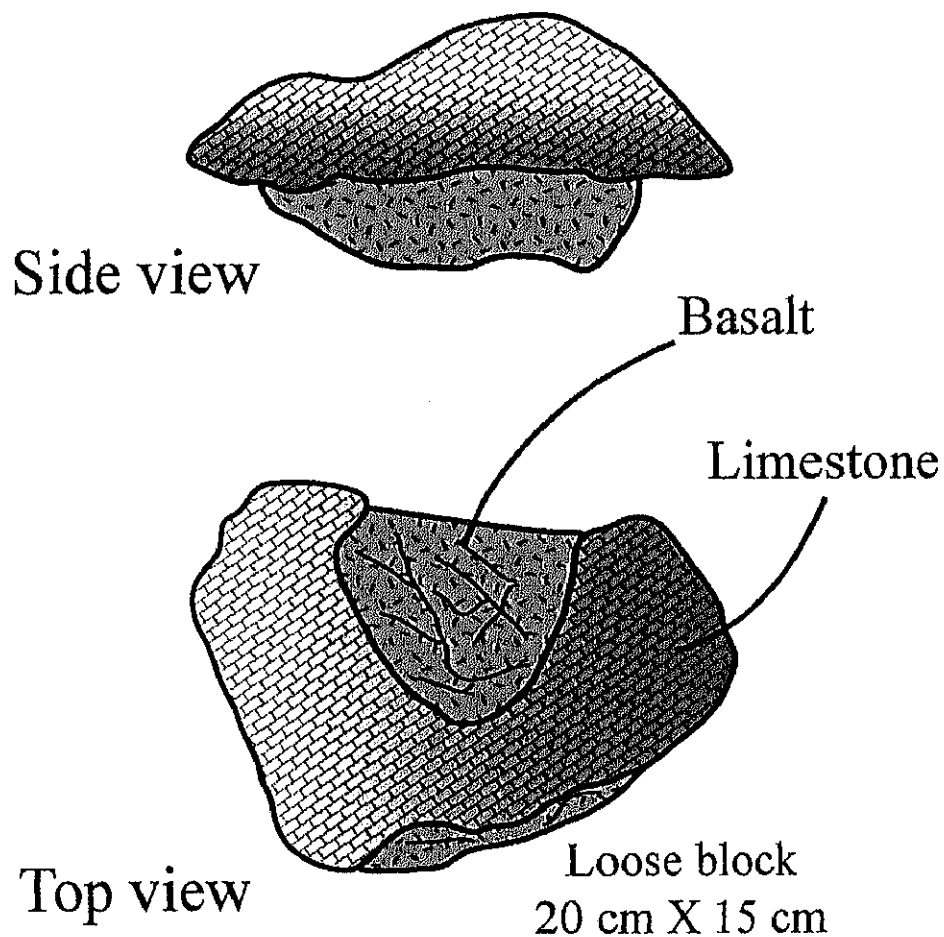


Fig. 31 Sketch of a "loose" block of basalt accompanied with limestone in the mélange at the same location as Fig. 29.

UTM 48P 0200421,1450822

N 13°06'36.1" E 102°14'12.2"

Foliation 335/65 E

Lination 155/20 S

Hanging wall moved to NW

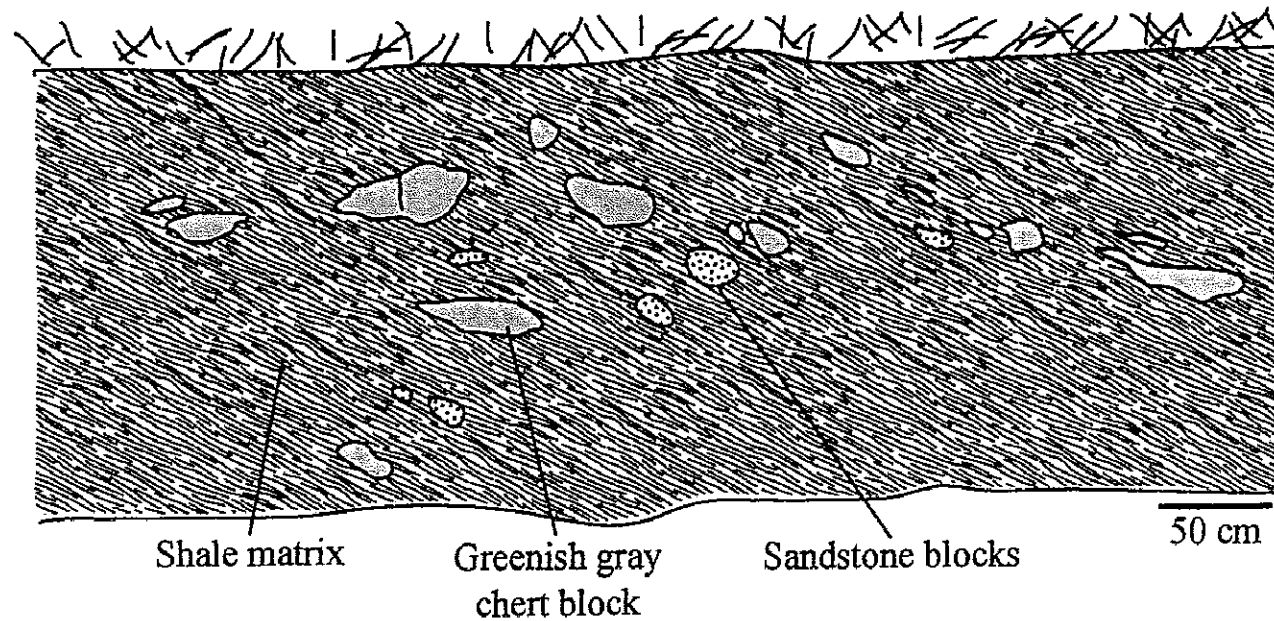


Fig. 32 Outcrop sketch of mélangé in the Soi Dao unit showing blocks of cherts and sandstones in shale matrix.

UTM 48P 0209961,1439046
N 13°00'15.8" E 102°19'33.6"
Highway 3210, ~ km 6

Joints :- 215/75 NW, 105/65 S

Fault :- 160/70 W, rake 47, NW (reverse, left-lateral fault)

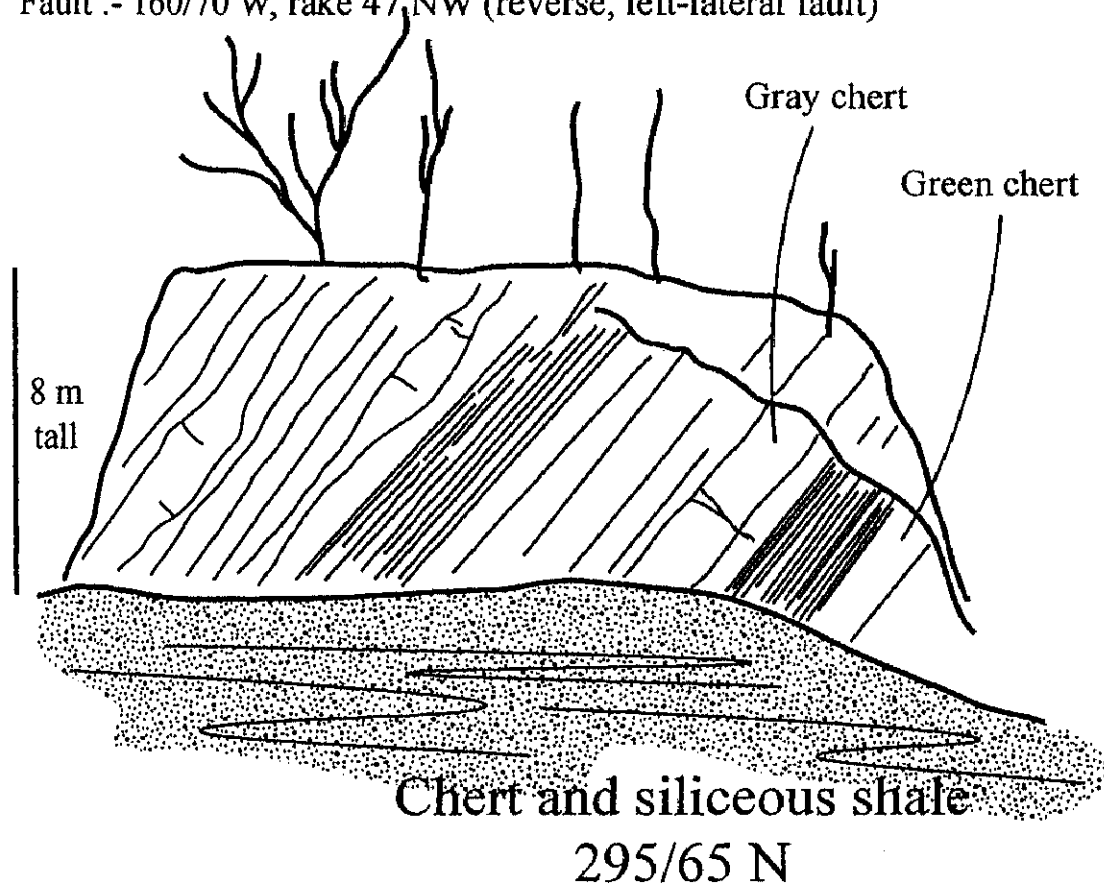


Fig. 33 Outcrop sketch of radiolarian-bearing gray chert in the Soi Dao unit along the Highway 3210 (~ km 6) showing a well-developed bedding.

fault contacts with limestones. Purplish brown basaltic clasts in matrix display aphanitic, porphyritic, and amygdaloidal texture. A lot of detrital chromian spinels are discovered from matrix of these volcanoclastic rocks.

Several highly weathered and sheared serpentinite associated with basaltic lavas are discovered as small outcrops near the Ban Thung Krang and Ban Mai villages along the Highway 317.

2.2.5 Pong Nam Ron Formation

The Pong Nam Ron Formation was named for the Triassic greywacke unit by Siwaborn et al. (1976) and was followed by later researchers (Salyapongse, 1992; Chaodumrong, 1992; Chutakositkanon et al., 2001a, 2002, 2003a, 2003b). Salyapongse (1992) and Chaodumrong, (1992) concluded that these sandstones represented syn-collisional sediments along the remnants basin of the collision zone between the Sibumasu and Indochina.

The Pong Nam Ron Formation is distributed in the southern part of the study area. It is exposed to the south of the Soi Dao unit, with an inferred fault-boundary contact. Quite dominantly, the sandstones correspond to fine-grained “feldspathic greywacke” and “lithic greywacke” following to Folk (1974)’s classification scheme (see later chapter). Weathered surfaces are pale gray to yellowish gray, and fresh surfaces are generally greenish gray to black. Each sandstone bed varies from 4-5 cm up to several meters (Plate 8a).

Shales of this unit are recognized as friable beds alternated with sandstone beds. Weathered color ranges from pale gray to dark gray, and on fresh color, the shale is dark gray to black. In general, shale beds range from a few cm to a few meters.

The sequences exhibit almost characteristics of turbidite deposits (Fig. 34). Sandstones and shales are monotonously alternated through several hundreds of meter or a few kilometers of stratigraphic sections. Frequently sandstone layers show typical sole marks as load casts, flute casts, and groove casts (Figs. 35 and 36; Plate 8b). Within the sandstone beds, the strata have sharp abrupt bases, and tend to grade upward into finer sand and silt. Cross-laminations are sometimes found. Some sequences display an almost complete Bouma sequence. The BDE divisions are more common than the complete ABCDE turbidites of a Bouma sequence. The transportation of sediments is concluded from sole marks of sandstone strata, especially flute casts and groove casts. Direction of currents measured from flute casts indicates that the sediments were derived mainly from south and southeast (Chutakositkanon et al., 2001a, 2002) (Fig. 36). In the rock unit, bryozoa, calcareous algae and other carbonate fragments are found as clasts or fossil fragments in sandstones under the microscope.

Considering the detrital chromian spinels, the Pong Nam Ron Formation yields detrital spinels from the lithic greywacke alternated with shale. Detrital chromian spinels are discovered as one of the accessory minerals in sandstones (less than 1 %). They are widely varied in size from 20 to 400 μm and display reddish brown to deep brown and black colors under the transmitted light.

UTM 48P 0203737,1422278
N 12°51'08.4" E 102°16'12.9"
Highway 317, km 29+880

Shale and silicified shale

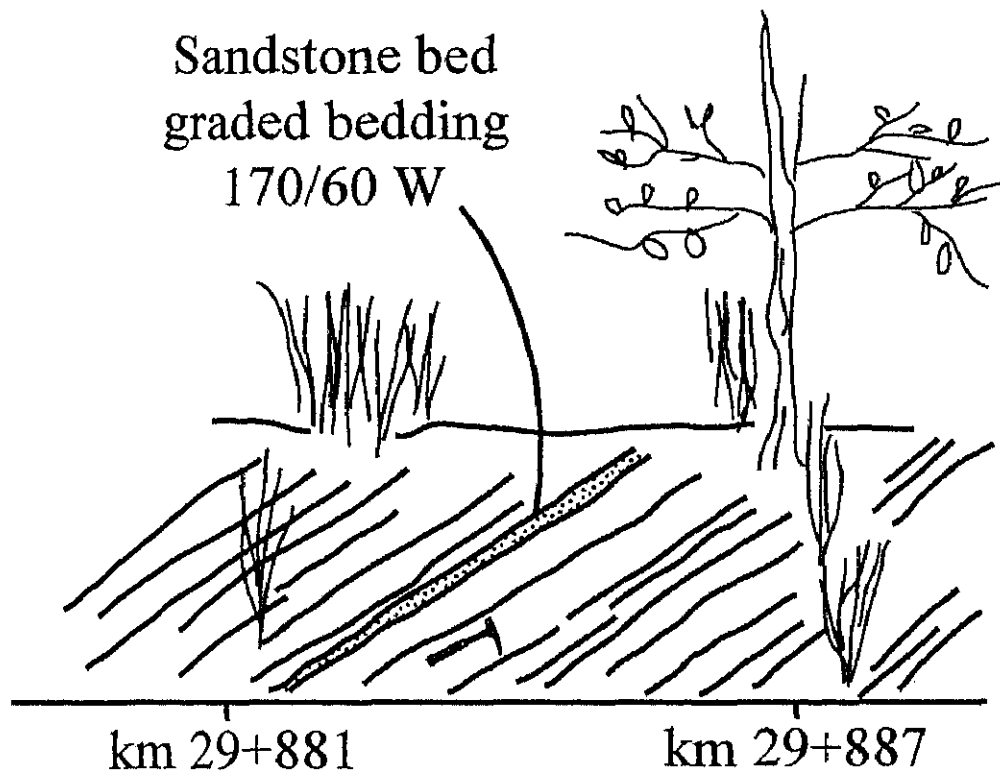


Fig. 34 Outcrop sketch of alternation of sandstone and shale along the Highway 317 (km 29+880) showing the characteristics of turbiditic sequence of the Pong Nam Ron Formation. Hammer in sketch is a scale.

UTM 48P 0207300,1435828
 N 12°58'30.5" E 102°18'06.1"
 Highway 3210, km 1+758

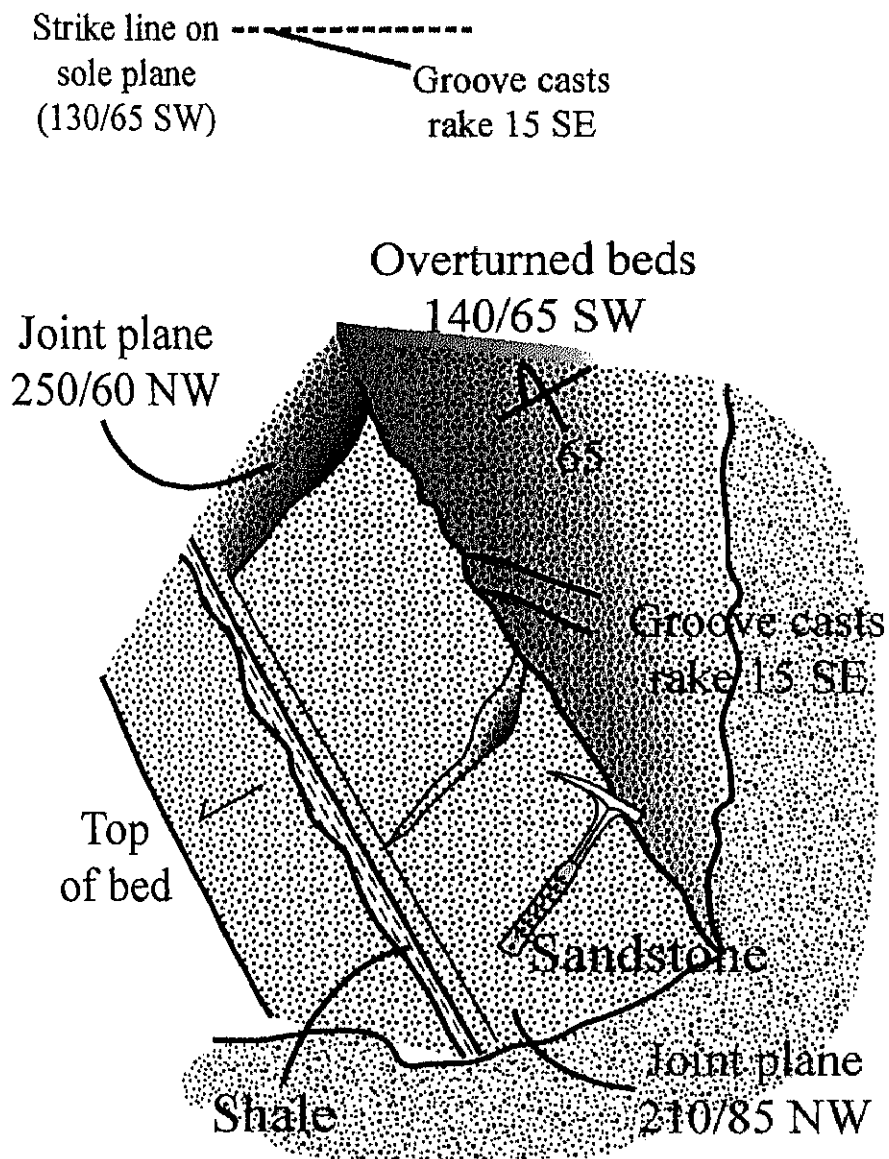
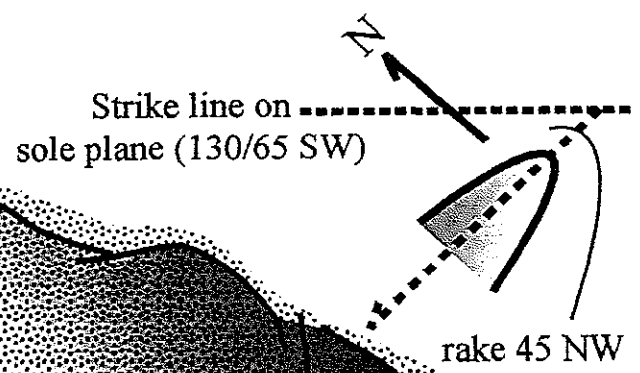


Fig. 35 Outcrop sketch of overturned bed of turbiditic sandstone in the Pong Nam Ron Formation displaying the groove casts on sole of bed. Hammer in sketch is a scale.

UTM 48P 0205884,1437315
N 12°59'18.7" E 102°17'18.7"
Highway 317, km 46+220



58

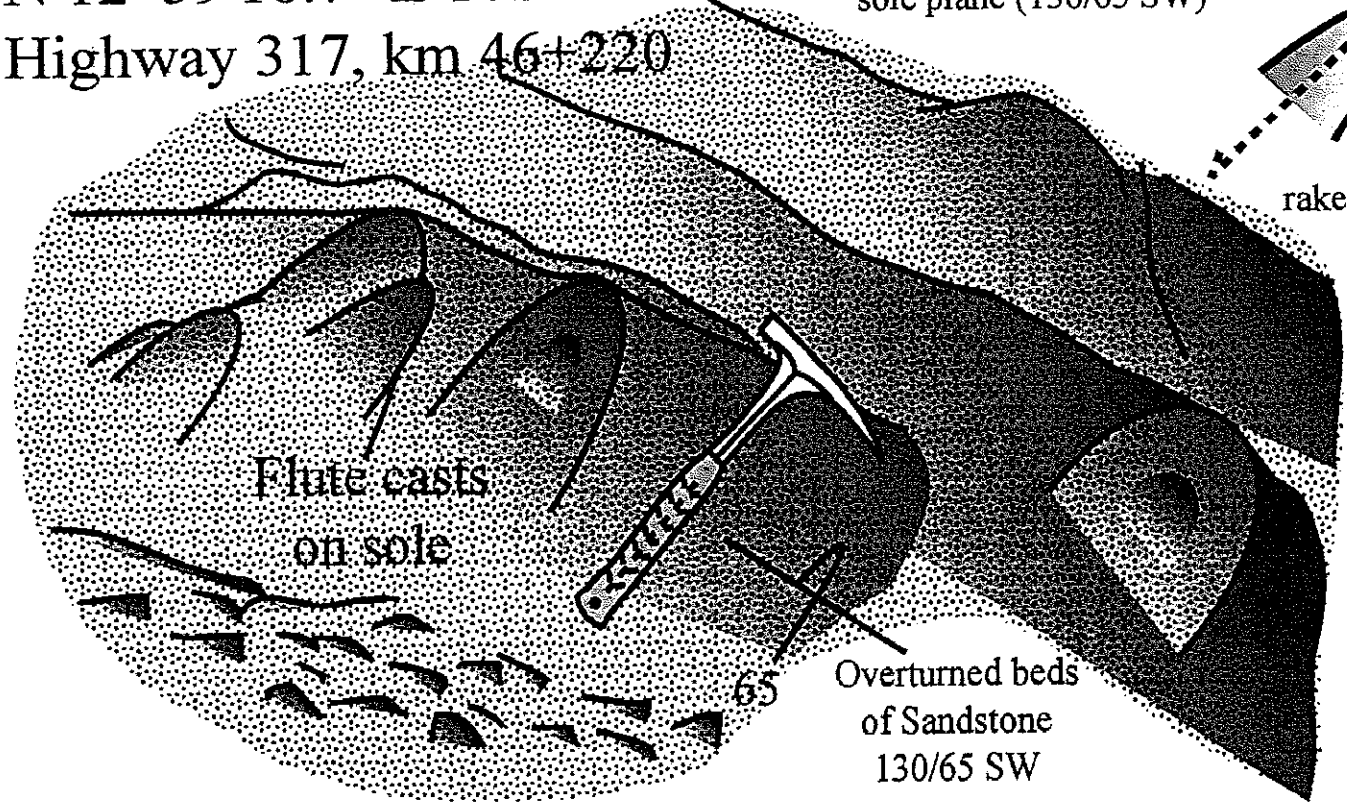


Fig. 36 Outcrop sketch of the overturned bed of turbiditic sandstone of the Pong Nam Ron Formation showing the flute casts on sole of bed. Measured paleocurrent from these flute casts is from the south.