CHAPTER V

ROCK MAGNETISM

Introduction

This chapter involves the analysis of magnetic minerals which preserved primary and secondary magnetization in the rock samples. The analyze of magnetic susceptibility and NRM intensity are included in the chapter. Procedures applied in this chapter refers to the technique of Applied Geophysics Lulea University , Sweden (Bhongsuwan , 1993). Signal of magnetization in the rocks is deduced from the chemical analysis (XRF), showing the value of FeO (total) up to approximately 2-3% (see Appendix H). It adequately reveals the signal of paleomagnetic direction (Van der Voo, 1993). Although however, types of magnetic carriers are not identified spectrographically in this study, Imsamut and others (1994) reported the presence of hematite in the red sandstone of the study using XRD analysis.

Magnetic Minerals

15 polished-sections and 21 thin-sections of Phu Thok samples are examined petrographically for magnetic minerals. All thin sections reveal that the opaque mineral is up to 2% of rock composition (see Appendix H). Petrographic investigation indicates iron- oxide cement and rare irregular slender-shape of opaque minerals. It is, therefore, believed that both types of iron-oxides are regarded to magnetic carrier (McElhinny, 1973 and Bhongsuwan,1993).

Types of magnetic minerals can be detected by reflected light microscope. Generally, the magnetic grains are very fine- to fine - grained minerals (0.01-0.1 mm).

They occur as tiny grains in matrix as well as cementing material in the porous areas of sandstone. It is noted that the stronger magnetization is encountered as the sandstones are coaser - grained. Reddish brown from stain perhaps (goethite) is usually found in all samples. From the study, the magnetic minerals can be separated into two types.

1. Detrital magnetic minerals

Detrital magnetic minerals are recognized by metallic luster, and their morphology. Identification of the minerals by ore microscope is referred from Wilson and Haggerty (1966), in McElhinny (1973) and Craig and Vaughan (1981). The detrital magnetic minerals in the Phu Thok rocks are divided into two types as the magnetite-hematite assemblage and hematite minerals.

Polished - sections from 5 selected samples (no. 37005, 37012, 37018, 37045, and 37105) are used to determine magnetic minerals. These mineral are mainly associated with the fine- to medium- grained sandstone. Size of the detrital grains are about 0.05-0.1 mm. Original magnetite is characterized by subhedral-auhedral, cubic cleavage system, gray color, isotropic grain (Figs. 5.1 and 5.2). It contains exsolution or oxidation lamellae (pseudomorph overprints) of the anisotropic, bright white to yellowish white, hematite or maghemite in almost all magnetite grains. Tarling (1983) also noted similar characteristics. Internal reflection of the magnetic grains are usually found as a deep red color.

The dominantly expected primary magnetic mineral in the rocks is detrital hematite. All polished-sections of various types of sandstones reveal that hematite grains are shown as the matrix of rocks (Figs. 5.3 and 5.4). Size of grains are about 0.02-0.1 mm. These are characterized by anhedral, anisotropic, bright white to yellowish white, very fined-grained (Fig.5.5). Reaction rims are common as alteration of hematite grains to goethite (Craig and Vaughan ,1981). However, some grains of hematite denoted the

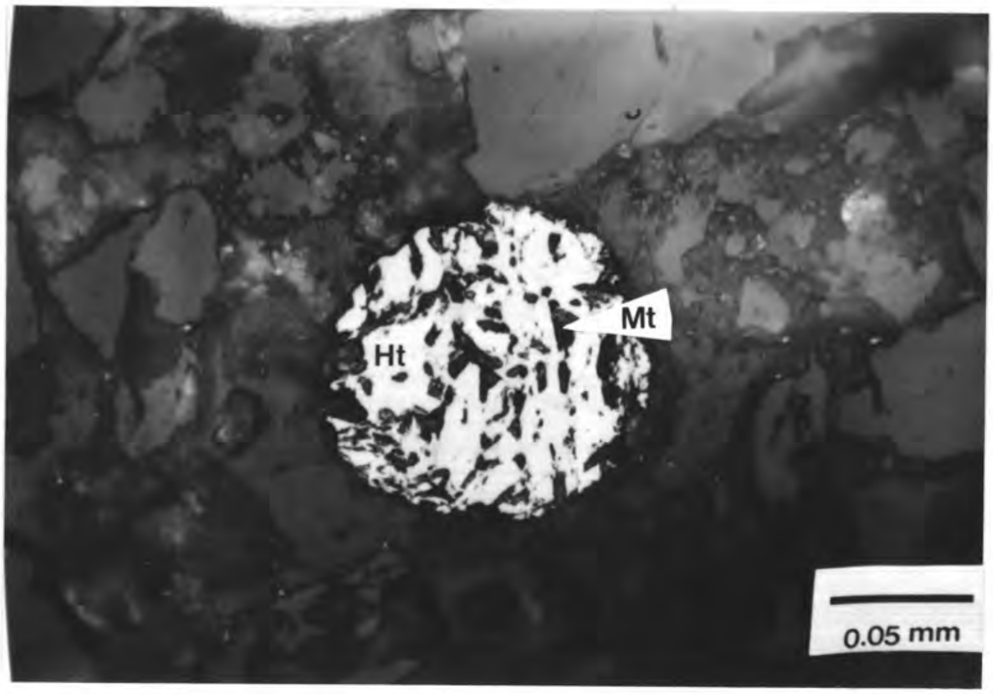

Figure 5.1 Polished-section sandstone of sample no. 37018 showing the detrital grains of subhedral, cubic cleavage system, gray color, isotropic grain magnetite (Mt) exsoluted by anisotopic, bright white to yellowish-white, hematite (Ht) (crossed-nicols).

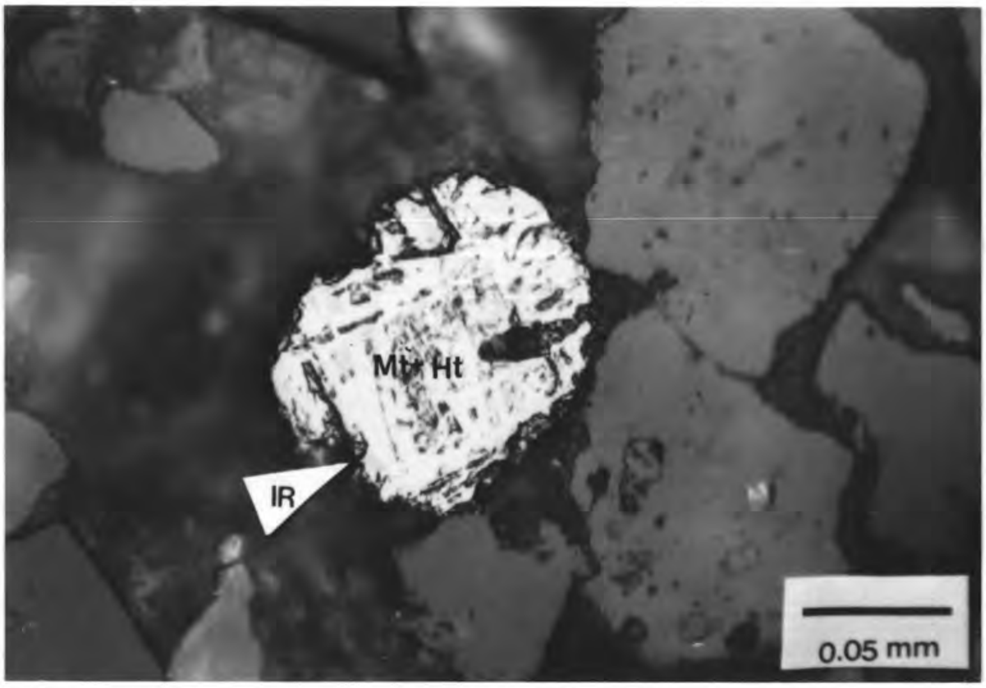

Figure 5.2 Polished -section of arkosic sandstone (no. 37005) showing the pseudomorph overprinted hematite on the detrital magnetite grains (Mt+Ht). Internal refraction (IR) usually found at the rim of magnetic grain (crossed-nicols).

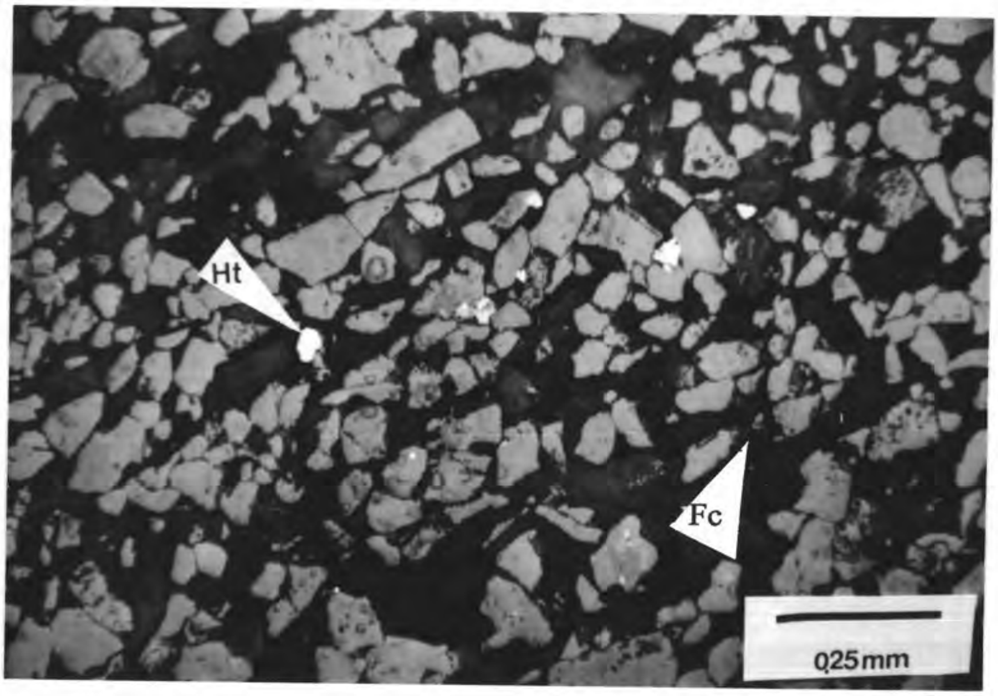

Figure 5.3 Detrital hematite (Ht) grains which occur as matrix of the red fine-grained sandstone (sample no. 37162). Ferrugenous cement (Fc) showing the deep red color (crossed-nicols in polished-section).

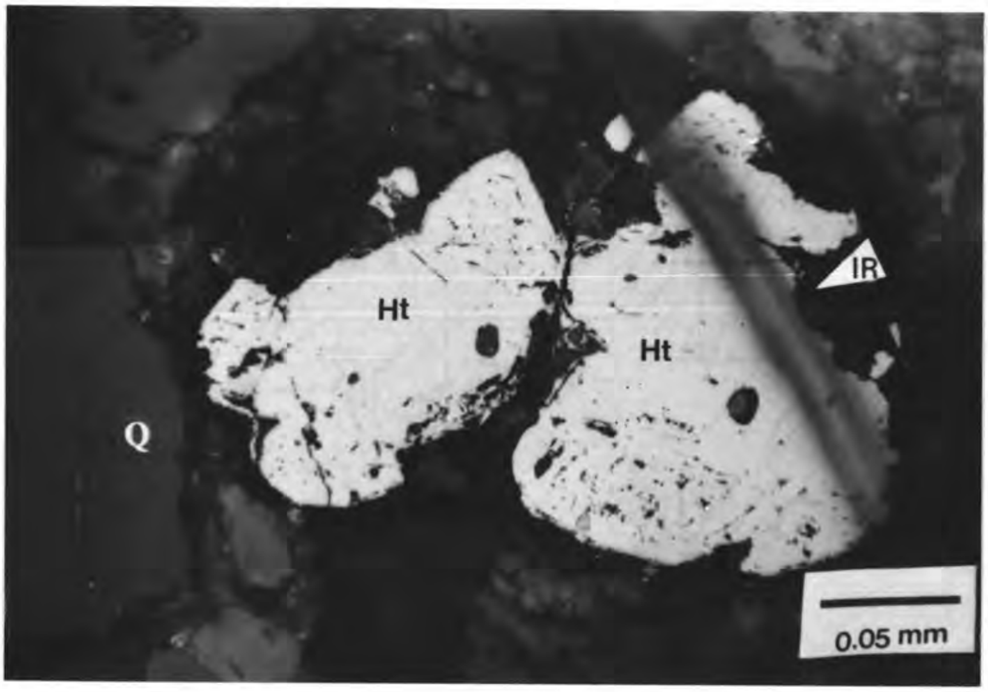

Figure 5.4 Closed up of detrital hematite (Ht) grain showing the internal refraction (IR) and some oxidation lamellae, bright white to yellowish-white within the hematite grain, arkosic sandstone (sample no. 37005). The photomicrograph also show quartz (Q) grain (crossed-nicols in polished-section).

very bright, whitish yellow to yellow, anisotropic and high birefringence (see Fig. 5.5). These grains are probably assumed the titanium - iron assemblage minerals or titanohematite minerals (see also Wilson and Haggerty ,1966 in McElhinny, op. cit. and Maranate, 1982).

2. Secondary magnetic minerals

Secondary magnetic minerals include iron-coated cement or goethite and secondary hematite as cement of detrital rock fragments. Generally, iron oxide-cement is assigned to the end of deposition of red-bed sandstone. If the diagenetic environment is oxidizing, the iron is reprecipitated as hematite or goethite which inturn converts to secondary hematite on ageing (Tucker, 1981). The length of time involved in the ageing process is the order of million years (Tucker, op. cit.). Therefore, remagnetization of goethite and secondary hematite were also encountered in the rocks.

The most common secondary magnetic minerals is goethite which occurs as a oxidation of iron coats around detrital sand grains or in ferrugenous cements. Petrographic studies reveal that the goethite is suitably located in porous areas of all various of arkosic rocks (Fig. 5.6). The goethite is characterized by amorphous, reddish brown, iron stained (Craig and Vaughan ,1981). Bhongsuwan (1993) also found these characteristic features in granites from southern Thailand. Some goethite grains are changed to euhedral secondary hematite (Fig 5.7) at higher temperature condition.

Petrographically, the samples studied show the occurrence of euhedral to subhedral hematite. The ore minerals as observed in arkosic rocks, especially very fine-grained, are regarded to be of secondary origin. Sizes of this secondary hematite (or protohematite of Tarling, 1983) is less than 0.01 mm. The hematite is inferred to be precipitated as micrograins in the porous area between goethite iron -oxide cement (see

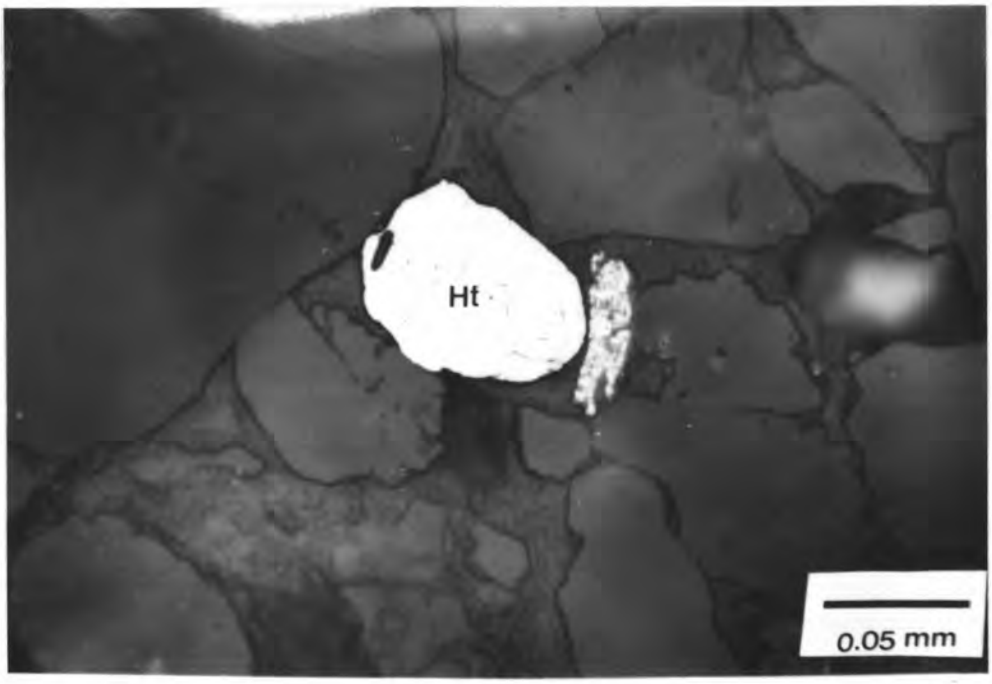

Figure 5.5 Polished-section description of arkosic sandstone (no. 37018) showing the detrital hematite grain (Ht) and probably titanohematite (yellow grain) as the matrix of the red-bed rocks (crossed-nicols).

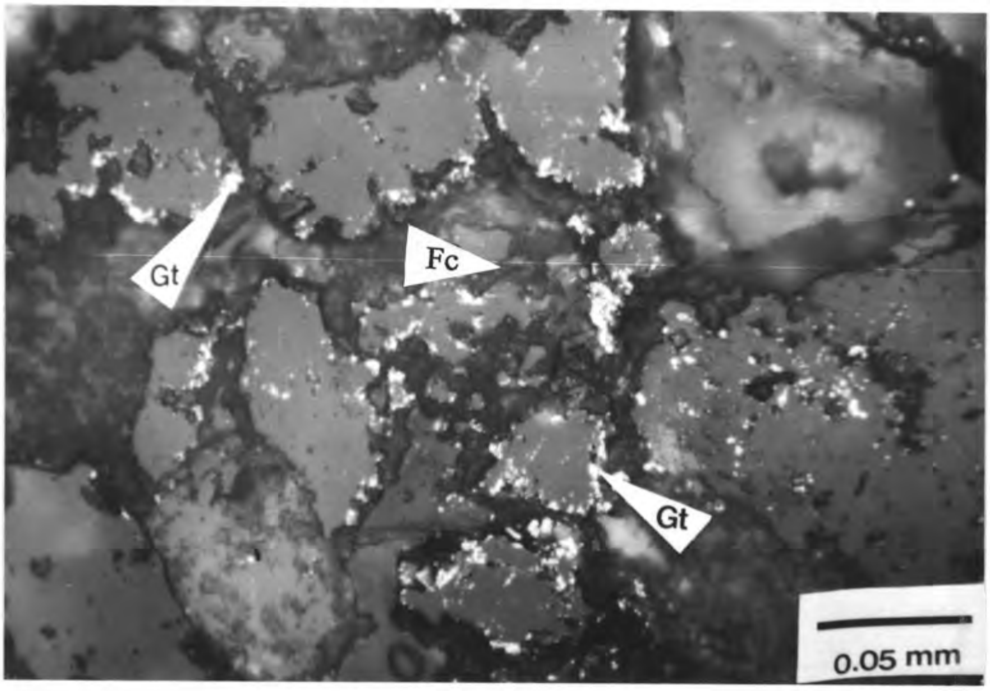

Figure 5.6 Amorphous goethite (Gt) and ferrogenous cement (Fc) is suitably located in porous areas of the arkosic rocks (no. 37145). Some amorphous grains are changed to secondary hematite (crossed-nicols in polished-section).

Fig. 5.7). The other type of hematite forms as a replacement product in small porous area in volcanic rock fragments or along rims of clasts of the rocks. These hematite grains are characterized by randomly oriented, subhedral to euhedral, hexagonal form, fibrous to lath shape, anisotropic and yellowish white color (Fig. 5.8). It is noted that the secondary hematite is stronger remagnetized than goethite (Tarling, 1983). Zijderveld and intensity plots also support this.

Magnetic Susceptibility and NRM Intensity

The explanation of the magnetic carrier in the Phu Thok rocks can be described by the relationship of magnetic susceptibility and magnetic intensity of NRM (Hronda and Kahan, 1991). The total of 124 samples are tested for magnetic susceptibility together with the remanent magnetic intensity (see Appendix F).

On the basis of the investigation, the Phu Thok Formation rocks have low magnetic susceptibilities, generally lower than 120×10^{-6}. Very fined-grained sandstone yields normally higher magnetic susceptibility than the coarser-grained arkosic sandstone. They have susceptibility ranging from 38 to 141×10^{-6} and averaging 65×10^{-6}. Arkosic rocks have susceptibility ranging from 18 to 106×10^{-6} and averaging 45×10^{-6}. The relatively high values ($> 100 \times 10^{-6}$) as detected from the samples (e.g. samples nos. 31082, 37002, 37044, 37122, 37153, 37160 and 37162) are from very fine-grained sandstone strata. The intensity of NRM of all rocks are normally less than 56 mA/m, however, NRM lower than 2 mA/m are common. Generally , very fine-grained sandstone gives certainly lower NRM intensity than the coarser-grained arkosic rocks. NRM intensity values of the very fine-grained sandstone range from 0.32 to 27.00 and average 1.0 mA/m and those of the fine- to medium -grained rocks are ranging largely from 0.49 to 55.00 mA/m with an average of 1.5 mA/m. However, some samples (e.g.,

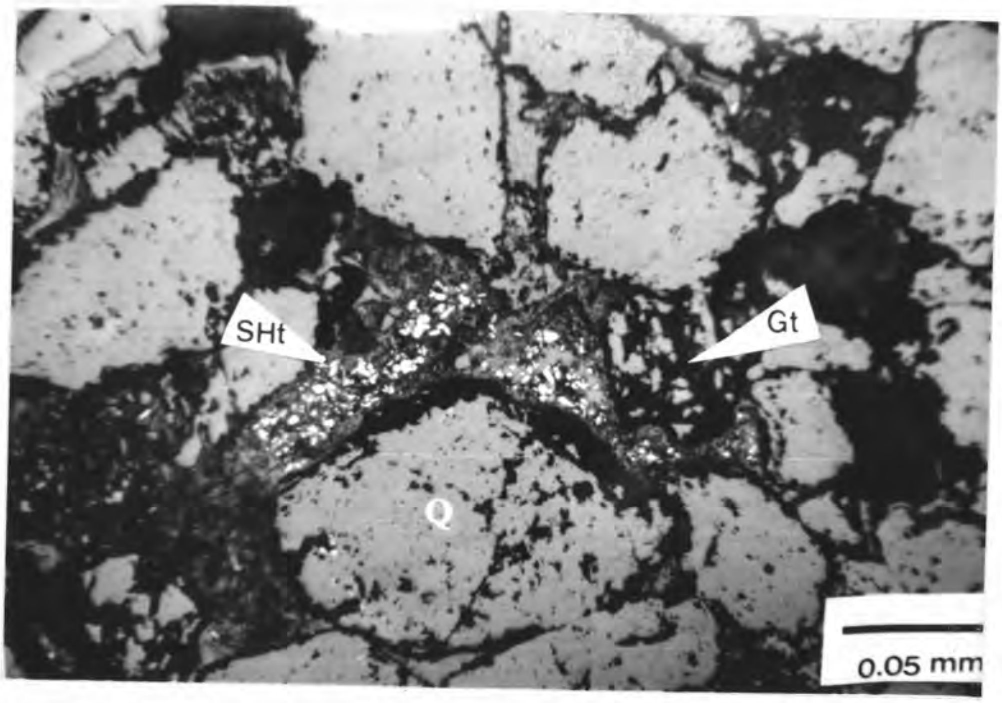

Figure 5.7 Photomicrograph of arkosic sample (no. 37022) showing the occurrence of yellowish-white secondary hematite (SHt) and goethite (Gt) at ferrugenous cement (crossed-nicols in polished-section).

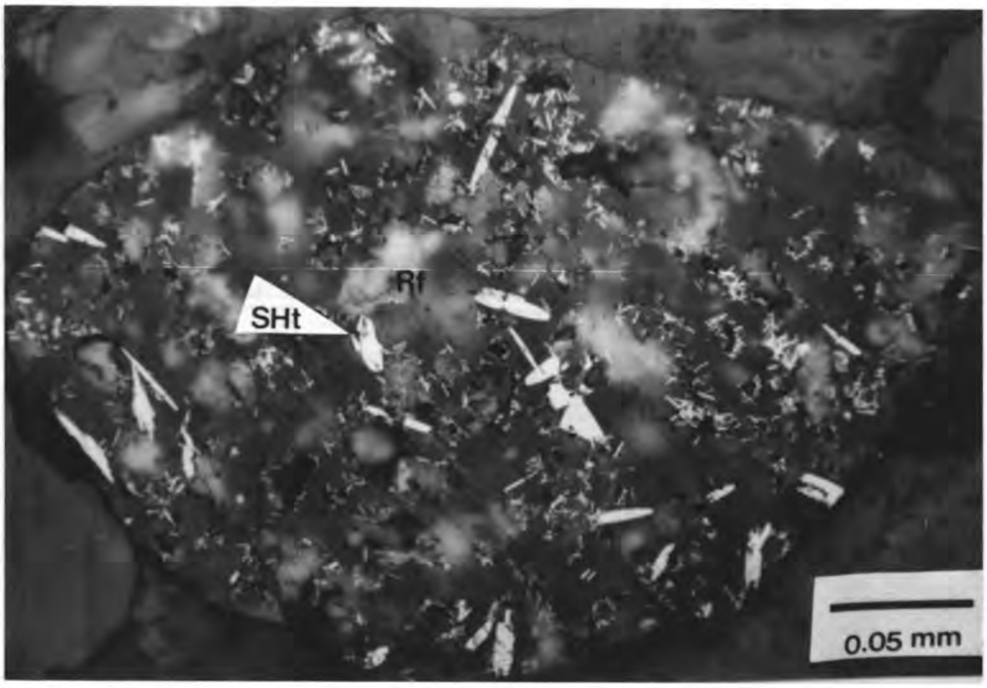

Figure 5.8 Closed-up view of a clast in arkosic sandstone (no. 37018) showing randomly oriented, subhedral-euhedral, hexagonal form, fibrous to lath shape, anisotropic and yellowish-white color secondary hematite (Sht) at the volcanic fragment (Rf) (crossed-nicols).

nos. 31068, 31077, 37003, 37016, 37060, 37101, 37118, 37146, and 37162) have rather high NRM intensity values (> 5.5 mA/m).

From this data, it is important to note that the similar types of magnetic minerals group are recognized in the rocks. However, the extraneous value of susceptibility and intensity point to the occurrence of ferromagnetic minerals. The lowest NRM intensity (0.32 mA/m) are believed to be a result of changing of the magnetic polarity more than the reasonable magnetic minerals.

The relationship of NRM intensity and susceptibility data which is calculated for Q-values (Fig. 5.9) can define the stability of magnetism in the rocks as determined from types of magnetic minerals (Koenigsberger, 1938 in Collison, 1983). The Q-values of rocks in the study area range from 0.3 to 21.9 and average 0.6 for the very fine-grained sandstone and 0.85 in fine- to medium- grained arkosic rocks. It is assumed that the stable or good recorders of the ancient geomagnetic field is recognized in the arkosic rocks (Collison, 1983). Hematite and goethite (and/or secondary hematite) are identified to the dominant magnetic carrier of the Phu Thok rocks. They are presented by low susceptibility (40-70 x10^{-6}), low NRM intensity (0.8-2 mA/m) and high Q-value (0.4-1). However, the special high susceptibility (119) and low Q-value (0.3) are observed in one sample (i.e. no. 37153). It may indicate that the various direction of magnetization was preserved in the ferromagnetic mineral such as magnetite (Hronda and Kahan (1991). Similar situation is also encountered in granitoid rocks of southern Thailand by Bhongsuwan (1993). The high NRM intensity and high magnetic susceptibility inferred to the stable primary magnetic direction are present on the magnetite grains.

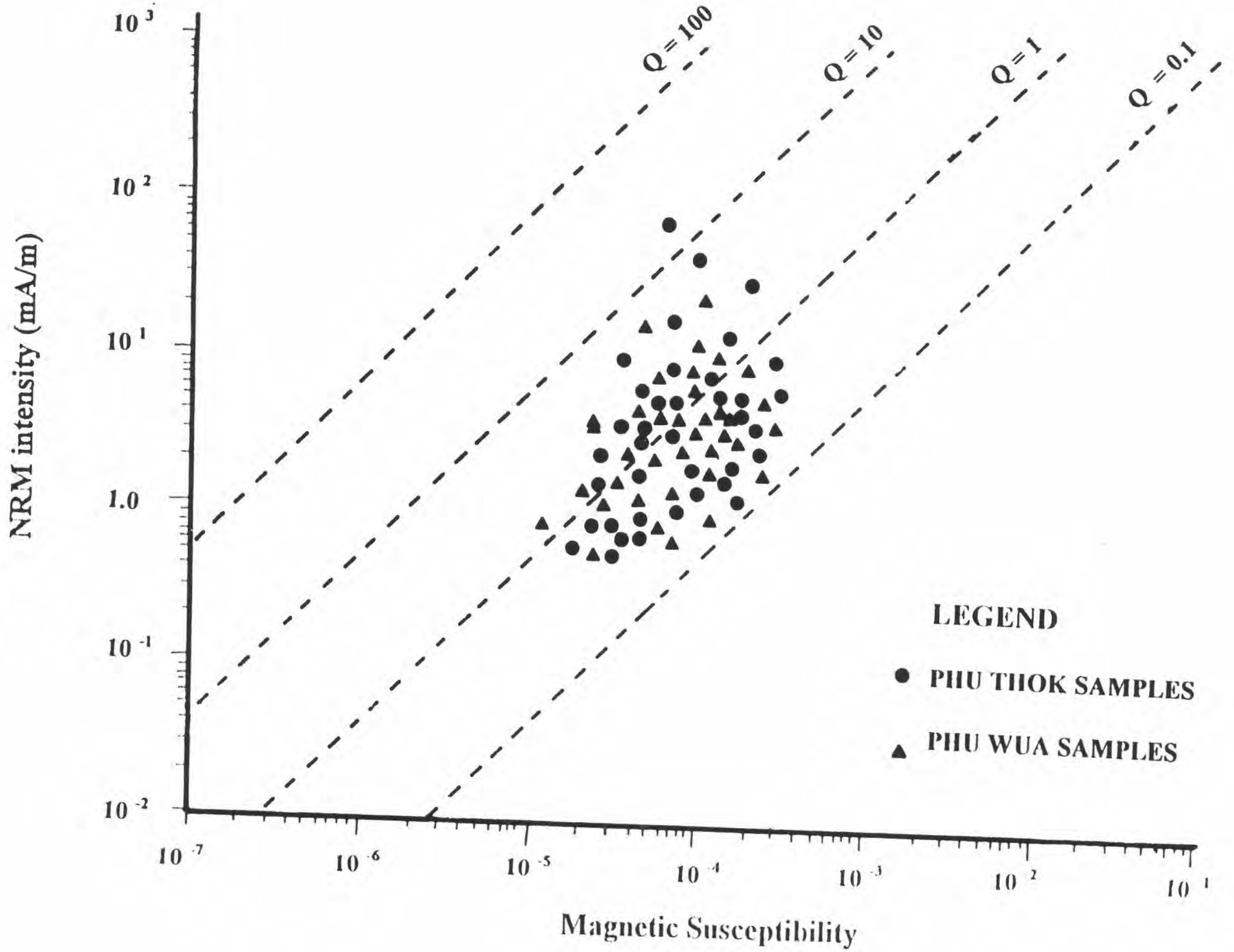

Figure 5.9 Relation between magnetic susceptibility, NRM intensity and Q-value of specimens.