IDENTIFICATION OF ADAKITE FROM THE SINTANG INTRUSIVES IN WEST KALIMANTAN

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ABSTRACT

The Sintang intrusives are widely exposed in West Kalimantan, and as reported by previous workers, consisting of high level intrusives of stocks, plugs, dykes and sills of microdiorite, microgranodiorite, granite/ micrograndite, quartz diorite, dacite, andesite, and minor rhyolite and rhyodacite. However, a careful study of published geochemical data gives a result that the rocks are of adakitic type. Considering the tectonic development of the South China Sea and northwest Kalimantan, the adakite was probably originated from magma as a result of melting of the subducted South Cina sea oceanic crust beneath Kalimantan continent. The subduction started in the Late Oligocene when the crust was still young.

Keywords : adakite, Sintang, intrusive, Late Oligocene

SARI

Intrusi Sintang tersingkap sangat luas di Kalimantan Barat, dan sebagaimana telah dilaporkan oleh para ahli sebelumnya, merupakan intrusi dangkal yang berupa stocks, sumbat, retas, dan *sill* batuan mikrodiorit, mikrogranodiorit, granit/mikrogranit, diorit kuarsa, dasit, andesit, serta sedikit riolit dan riodasit. Namun demikian, hasil studi yang lebih teliti terhadap data geokimia yang sudah diterbitkan menunjukkan bahwa batuan tersebut bersifat adakit. Dengan mempertimbangkan perkembangan tektonik Laut Cina Selatan dan daerah barat daya Kalimantan, kemungkinan adakit berasal dari peleburan kerak Laut Cina Selatan di bawah Benua Kalimantan. Penunjaman dimulai pada akhir Oligosen ketika kerak masih berumur muda.

Kata kunci : adakit, Sintang, intrusive, Oligosen Akhir

INTRODUCTION

A study of rock type in arc systems is important, because of its relations to the origin and magma genesis. While most arc magmas are produced by melting a mantle wedge above a subducting slab, adakite is believed to be the result of subducted oceanic lithosphere melted magmas (Defant and Drummond, 1990; Peacock *et al*., 1994).

In West Kalimantan, the Sintang intrusives are found in the Melawi to the south and in the Ketungau Basins to the north. The rocks consist of predominantly intermediate to acid rocks of high-level stocks, plugs, dykes and sills of microdiorite, micrograndiorite, granite/microgranite, quartz diorite, dacite, andesite, and minor rhyolite, rhyodacite. The intrusive resulted from a calc-alkaline magmatic event of Late Oligocene to Early Miocene post-subduction (Heryanto *et al*., 1993). Geochemical data, including major, trace and rare earth elements, of the intrusives are available (Williams and Harahap, 1987; Heryanto *et al*., 1993; Harahap, 1987). However none of those authors describe the present of adakite in the Sintang intrusives. The adakite in West Kalimantan was firstly recognized and reported by Prouteau *et al*. (1996). They studied six granodiorites or micrograndiorites and two dacites from the Sintang intrusives and found that only these two dacites show "normal" arc geochemical characteristics, while the rest four samples indicate adakite type rocks.

This paper discusses the possible adakitic rocks of the Sintang intrusives in West Kalimantan (Figure 1), based on a detailed study of published geochemical data mentioned above. All samples belong to the Sintang intrusives, which were collected during the geological mapping activities by the Indonesia-Australia Geological Mapping Project, a joint project between the Indonesian Geological Research and Development Centre and the Australian Bureau of Mineral Resources. The study includes geochemical comparison of the rock from West Kalimantan to that of the adakite from Adak Island, Aleutian Islands, Alaska (Defant and Drummond, 1990) as well as to the geochemical characteristics of the "normal" arc rocks from the subduction zone environment.

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GEOLOGY

The Late Cretaceous - Late Eocene collision of the Schwaner arc with the Eurasia plate produces three different geological domains in West Kalimantan (Williams *et al*., 1988). They are Schwaner Mountain in the south consisting of granite and metamorphic rocks; Northwest Kalimantan Domain in the north comprising schist, deformed granite, sedimentary and volcanic rocks; and mélange and associated accretionary deposits (Figure 1). There are two mélange zones, the Boyan zone in th south and Lobok Antu/Kapuas in the north. In the top of accretionary and outer shelf deposits and onlap the other domains, sediments are deposited in two basins (the Melawi Basin in the South and Ketungau and Mandai Basin in the north). Williams and Harahap (1987) postulated that the Northwest Kalimantan Domain was probably an allochtonous accreted continental terrane. The mélange zones was interpreted as being subduction-related, and the Melawi and Ketungau Basins were fore-arc basins related to different subduction zones.

Magmatic activities are recognized from the widespread intrusive and volcanic rocks. The Sintang intrusives of Tertiary age (Heryanto *et al*., 1993) are widely distributed in West Kalimantan, and are probably as the result of the Late Oligocene - Early Miocene subduction occurred in Kalimantan (Hamilton, 1979; Carlile and Mitchell, 1994). The subduction involved the South China Sea oceanic crust subducted beneath Kalimantan Continent produced a magmatic belt, that could be traced approximately following the border between Indonesia and Serawak, Malaysia. However, Williams and Harahap (1987) implied that the Sintang intrusives were not subduction-related rocks, but it might relate to post-subduction magmatism. In the Sintang Sheet Area, the intrusives discussed in this paper are found in the Melawi Basin to the south and in the Ketungau Basins to the north. The intrusives consist of mostly granodiorite and few diorites or subvolcanic andesites.

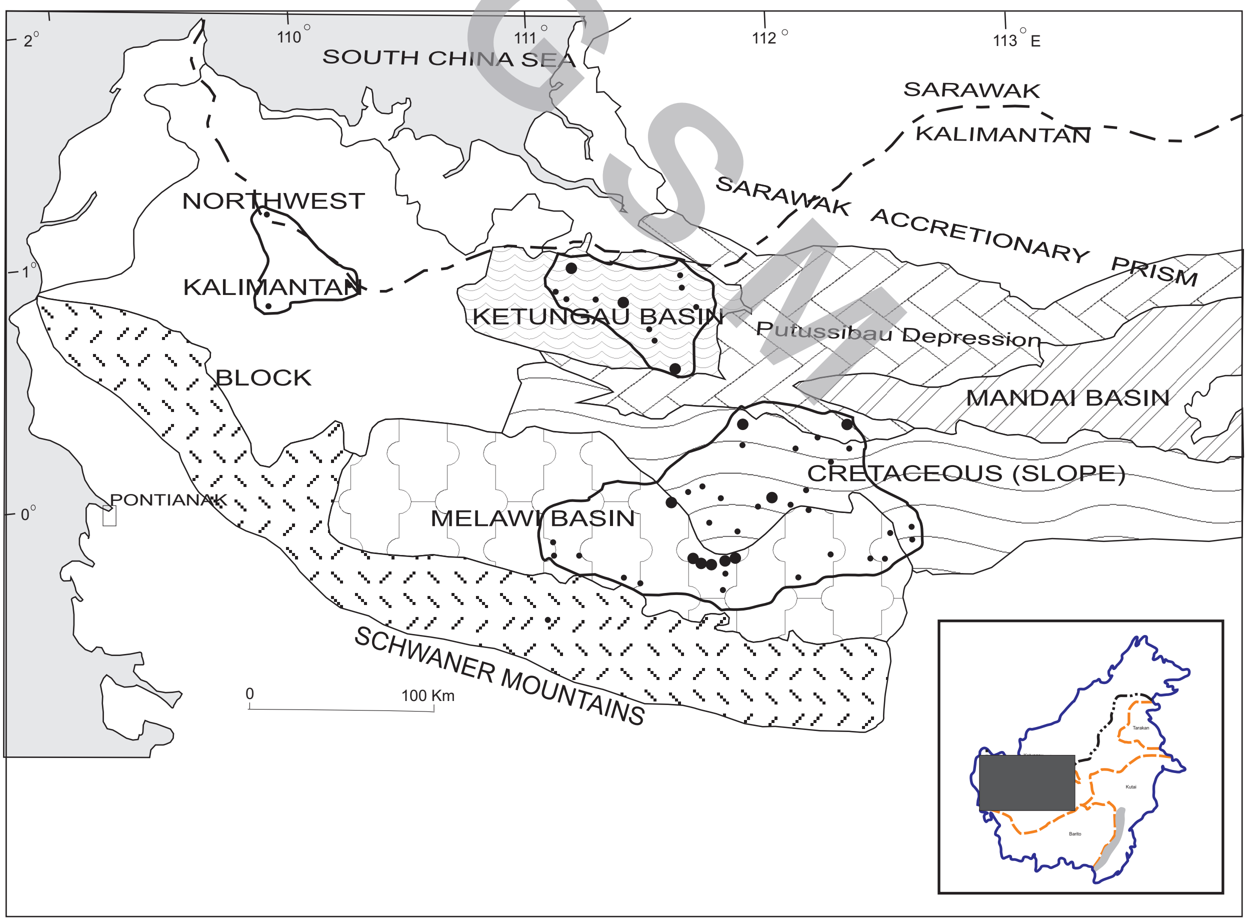

Figure 1. The regional geology of West Kalimantan showing the distribution of the Sintang intrusives discussed in this paper. (Modified from Williams and Harahap, 1987, Figure 2)

Rocks Derived From Melting of Subducted Lithosphere

It is generally accepted that most of the arc magmas are derived from melting of the mantle wedge, induced by hydrous fluids released during dehydration reactions in the subducted lithosphere. Tholeiitic and calc-alkali basaltic magmas in arc environment are produced by partial melting of the mantle, and subsequently evolve by fractional crystallization processes to more silicic magmas of basalt, andesite, dacite, and rhyolite (*e.g.* Foden and Green, 1992; McCulloh and Gamble, 1991; Crawford *et a*l., 1987). During the crystal fractionation, some other processes (such as assimilation and magma mixing) may or may not involve. However, in several arcs, rocks with specific geochemical characteristics, called adakite, are believed to be derived from magma resulted from melting of subducted oceanic crusts (e.g. Defant and Drummond, 1990; Drummond and Defant, 1990; Peacock et al., 1994). The terminology of adakite was used by those authors as a rock with ≥ 56 SiO_2, ≥ 15% Al_2O_3 (rarely lower), < 3% MgO, low Y and HREE (heavy rare earth elements) and high Sr compared to common arc andesite-dacite-rhyolites. Other geochemical charac-teristics are similar to island arc andesite-dacite-rhyolites, for example low concentration of HFSE (high-field strength elements) and high content of large ion lithophile elements (LILE). Petrographically adakite varies, with plagioclase and amphibole commonly present, but clinopyroxene and ortho-pyroxene are also common constituents when the rocks are MgO-rich. The rocks are rarely associated with basalts or basaltic andesites, but if so the basalt and basaltic andesite are very high concentration in LILEs.

Sintang Intrusives

Brief rock description and ages

The Sintang intrusives consist of predominantly intermediate to acid rocks of high-level stocks, plugs, dykes, and sills of microdiorite, microgranodiorite, granite/microgranite, quartz diorite, dacite, andesite, and minor rhyolite, rhyodacite, and gabbro or dolerite and basalt (Heryanto *et al*., 1993), with microdiorite and microgranodiorite are the predominant rock types (Williams and Harahap, 1987). However, Heryanto *et al*. (*op. cit.*) implied that the basic rocks (gabbro, dolerite, basalt) were probably Triassic (209 my) in age, which belong to the Betung volcanics. The rock association, with dacite as a dominant rock type, is unlike the "normal" arc-related magmatic environ-ments. The intrusives are generally porphyritic and coarser hypidiomorphic variants. Together with plagioclase, amphibole is a very common mineral phase in the leucocratic rocks, although pyroxene is also found in sample of melanocratic rocks from the Ketungau Basin. The groundmass consists of very fine to microcrystalline and for more acid rocks show myrmekitic intergrowth or pilotaxitic textures (Heryanto *et al*., 1993).

K/Ar analysis of samples show a range of 30.4 to 23.0 my (Late Oligocene - Early Miocene) for the rocks from the Melawi Basin, and 17.9 - 16.4 my (Lower-Middle Miocene) for the rocks from the Ketungau Basin (Williams and Harahap, 1987; Heryanto *et al*., 1993). Kirk (1968) reported that the intrusives from the Ketungau Basin in Serawak gave a range of age from 19 to 16.5 my (Lower-Middle Miocene).

The significant of geochemical characteristics

In general, the rocks show arc-related that vary from dolerite to rhyolite with SiO_2 content ranging from about 54 76 wt %, but mostly ≥ 56 wt % (Harahap, 1987; Heryanto *et al*., 1993). The dolerite (≈ 49% SiO_2) is doubtful and, as mentioned by Heryanto *et al*. (1993), the rock probably belonged to the Triassic Betung volcanics. However, detailed obser-vation on rock geochemistry shown clear significant characteristics which differed from that of "normal" arc rocks. Rocks with ≥ 56 wt % SiO_2, mostly contain high Al_2O_3 (15.22 - 18.78 wt %), high Sr concentration (416 1099 ppm), low Y (1 - 18 ppm) and Yb (< 1 - 2.5 ppm) content. These characteristics indicate an adakite type rock, but Harahap (*op. cit.*) and Heryanto *et al*. (*op. cit*.) have never described the rocks as adakite, and they rather conventionally called the rocks as a granitoid member (*e.g.*, granodiorite, quartz diorite, granite, and the volcanic equivalents). Adakite in West Kalimantan was also recognized and reported by Prouteau *et al*. (1996) as part of the Sintang intrusives. They studied six granodiorites or microgranodiorites and two dacites, and found that only these two dacite showing "normal arc" geochemical characteristics, while the rest indicated adakite type of rocks.

The trace element abundance of adakitic rocks from the Sintang intusives are shown in spidergrams

(Figure 2). The figure shows that there are no differences between the trace element characteristics of the adakite and that of the rock of "normal" island arcs, in the case of LILE and HFSE abundance. Like many other subducted related rocks, the adakite type rock from West Kalimantan shows enrichment in LILEs (Rb,Ba, K, Sr) and depletion in HFSEs (Nb, Ti, Zr) compared to that of mid-ocean ridge basalts (MORBs), but the LILEs are comparable with the ocean island basalts (OIBs). However, as mentioned above, the high content of Al_2O_3 and Sr and low concentration of HREE (Y and Yb) of the Sintang intrusives may not be simply interpreted as rocks resulted from magmas of "normal" island arc environments as mantle derived magma. Those geochemical characteristics imply adakite type rocks originated from crustal melting magmas in a subduction system. This possibility will be discussed later.

The Sr and Y data of the Sintang intrusives are plotted in the Sr/Y ratios against Y (Figure 3). For comparison are the andesite-dacite-rhyolite from other arc rocks, which are Haruyan volcanics (Hartono, 1997), Macolod Corridor and Bataan Segment volcanics, Souther Luzon arc (Defant *et al*., 1991). The field of adakite (Defant and Drummond, 1990) is also plotted. The figure shows that majority of the Sintang intrusives have low Y (< 20 ppm) and high Sr (expressed by high Sr/Y ratios) concentrations, and are distributed in the adakite field of Defant and Drummond (1990), which is different from that of the "normal" arc rocks.

Relationship Between Magma Genesis and Tectonic Development

Based on experimental studies and field observation, several scientists (Drummond and Defant, 1990; Defant and Drummond, 1990, Peacock *et al*., 1994) believe that adakites are associated with subduction zone derived from magma of basaltic sources (melting of basalt). The sources could be a subducted oceanic slab or thick, underplated lower crusts. An experi-mental work conducted by Defant and Drummond (1990) shows that trace element geochemistry of adakite is consistent with a derivation of young, hot (< 25 my) subducted slab melting. The conclusion supports earlier works on the high-magnesian andesite volcanic suite in Aleutian (Kay, 1978) and in southernmost Chile (Stern *et al*., 1984). In those two areas the basaltic sources have been described as potential subducted slab melts. However, Peacock *et al.* (1994) noticed that other mechanism was possible, *i.e*. melting of underpalted mafic lower crust or previous subducted oceanic crust. They developed the argument based on field data that in New Guinea and Baja, adakitic suites occured in an area where there was no modern subduction.

Taking into account the tectonic development of the South China Sea and northwest Kalimantan, those two models mentioned above might be applied in the generation of magma producing the Sintang adakite. Hamilton (1979) implied that the depth of the deepest part of the South China Basin was 4,000 m indicating the crustal structure in this basin was oceanic. The age of the oceanic crust is not older than Late Creataceous, and might be entirely Tertiary based on the depth and thin abyssal-plain sediments. The adakite of the Sintang intrusives exposed in the Melawi Basin (30.4 to 23.0 my) probably resulted from the Late Oligocene - Early Miocene subduction of the South China Sea oceanic crust beneath Kalimantan. Hence, the adakite exposed in the Melawi Basin might be derived from magma as a result of melting of the South China oceanic lithosphere, in which at that time the crust was still young.

CONCLUSIONS

The Sintang intrusive is widely exposed in West Kalimantan as a product of arc magmatism. The previous researcher (Heryanto *et al*., 1993; Williams and Harahap, 1987) called the rocks from the Sintang intrusive as a member of leucocratic granitoid rocks, such as microdiorite, microgranodiorite, granite/microgranite, quartz diorite, dacite, andesite, minor rhyolite, and rhyodacite. By evaluating geochemical data, it is concluded here in this paper that most of the Sintang intrusive rocks are adakite produced by melting of the young oceanic South China Sea crust. The high-Al and Sr contents and low concentration of HREE (Y and Yb) are the characteristics of the adakitic rocks. The nomenclature has important implications for the origin of magma. While rocks from "normal" arc mostly derived from mantle melting magma, adakite was believed to be derived from oceanic crust melting.

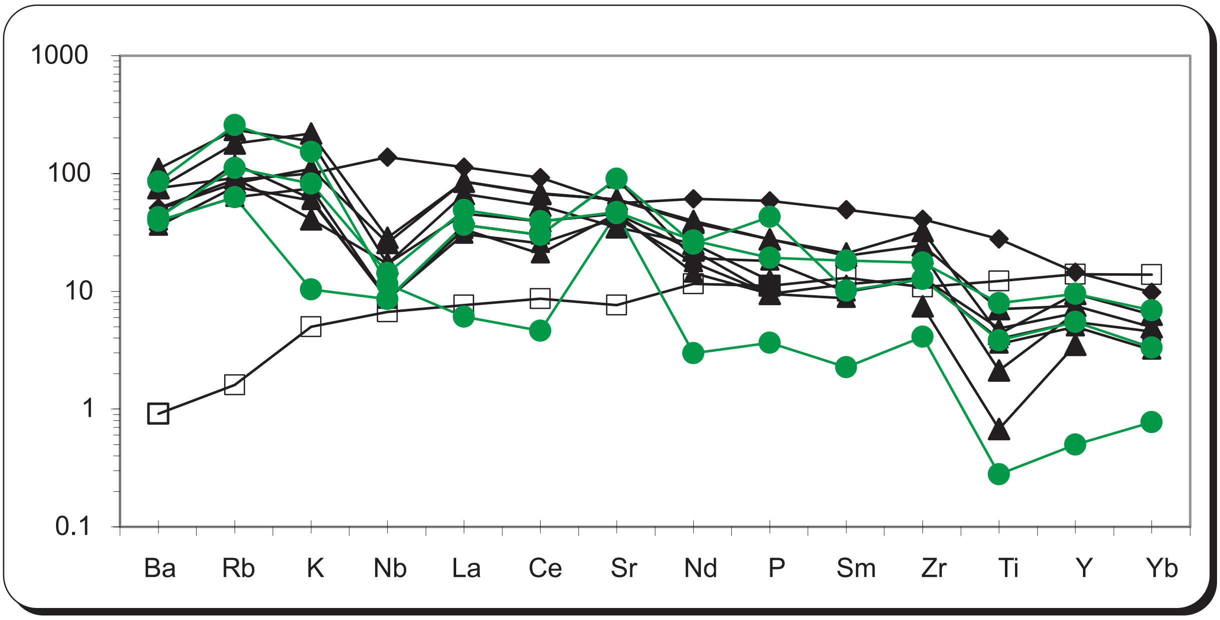

Figure 2. Spidergram of the trace element abundance of the Sintang intrusives (data sources : triangles by Heryanto *et al*., 1993 and circles by Harahap, 1987). For camparison of the trace element abundance of MORB (square) and OIB (diamond) are shown.

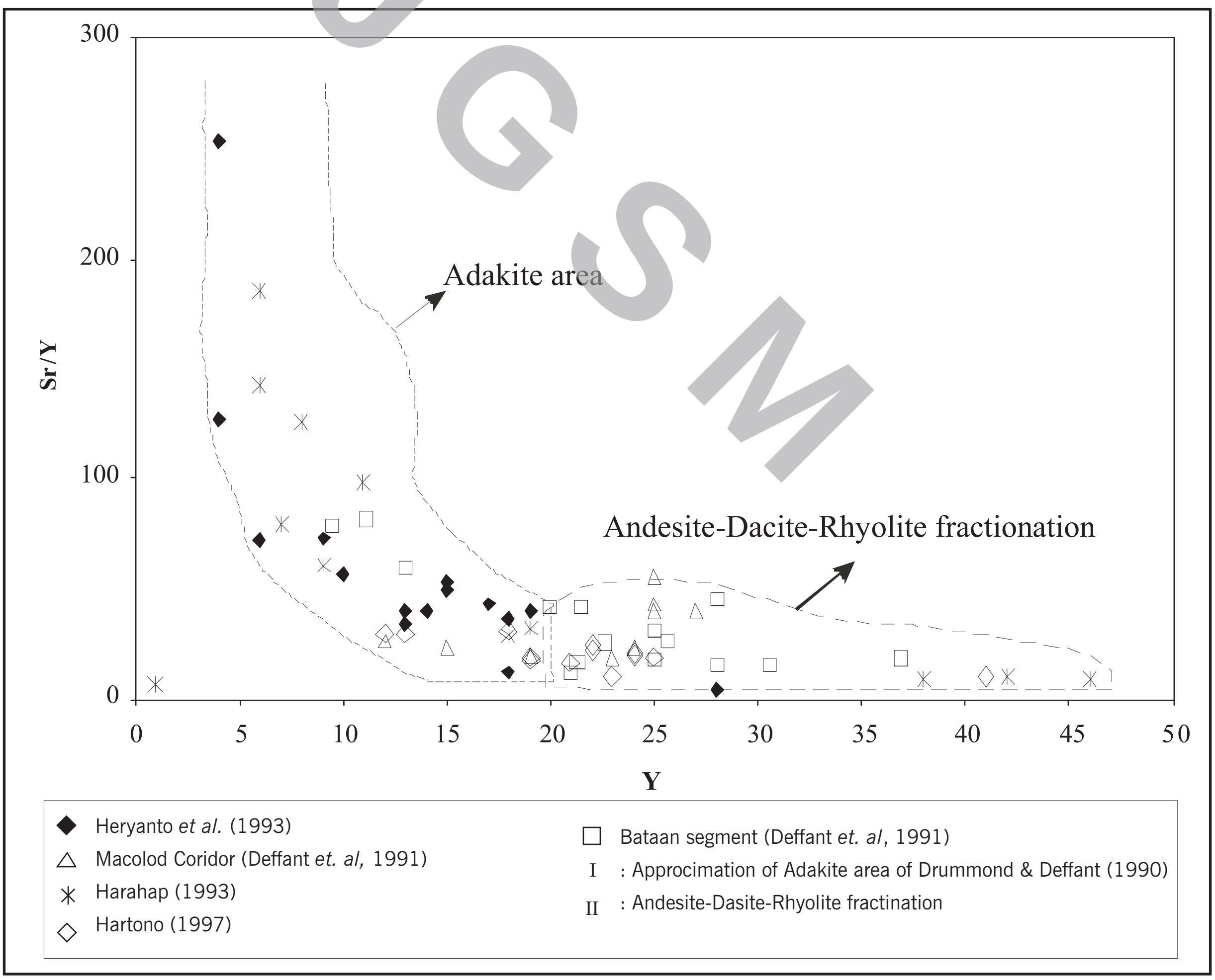

Figure 3. Sr/Y vs Y plot of the Sintang intrusives (data sources : Heryanto *et al*., 1993 and Harahap, 1987). For comparison are the data from "normal" islands arc rocks : the Cretaceous Haruyuan volcanics, Souther Luzon arc (Defant *et al*., 1991), and area of adakite (Drummond and Defant, 1990). The area of andesite-dacite-rhyolite fractionation is also shown.

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