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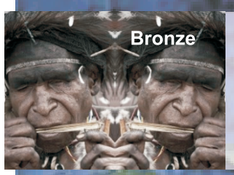

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TABLE OF CONTENTS

Geological Setting and Geochemical Approaches for Uranium Exploration in Papua

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ABSTRACT

With regards to the uranium exploration efforts in Indonesia, Papua is the area with least exploration activities compared to other major islands. Several preliminary geological and geochemical surveys have been done, and focused on the possible occurrences of the intrusive type uranium deposits. This paper is dealt with the research results on the possible occurrences of other types of uranium deposits, including sandstone-and-carbonate-hosted and unconformity-related systems in Papua, which are in line with recent concepts and understanding of tectonic and basins formation/deformation. This research result suggested some anomalies which are related to sandstone uranium deposits in Tipuma Formation, and carbonate uranium deposits in Quaternary Mokmer Formation and Oligocene Wainukendi Formation.

Keywords: uranium exploration, intrusive, sandstone, carbonate, unconformity-related

INTRODUCTION

With regards to the uranium exploration efforts in Indonesia, Papua is the area with least exploration activities compared to other major islands. Several limited preliminary surveys have been conducted in the Papua Bird Head area, (Arfak Mountain and Siwi), in the Papua Bird Neck (Nabire), and in the Papua Bird Body (Nalca). The target of the survey is to localize the possibilities of uranium occurrences related to: (1) the intrusive rocks of the Permian to Triassic Anggi, Kwatisore, Netoni, and Malaiurna Granites which are located in the Bird Head and Bird Neck areas, (2) the concept of unconformity related type deposits within the old rocks (pre-Paleozoic sedimentary rocks), and (3) the possibilities of carbonate type uranium deposit in Tertiary Limestone in Biak area. Some selected areas are described to figure out the possibilities of uranium occurrences in Papua based on geological setting and geochemical approaches. Up to now the field data availability is limited due to the difficulties in conducting field works especially in the main area of Bird Body of Papua.

GEOLOGICAL SETTING AND POSSIBLE URANIUM OCCURRENCES

The target of uranium exploration in Papua is to localize the possible uranium mineralization of various deposit types, i.e. intrusive, sandstone, unconformity related, and carbonate, but do not closed the opportunities of other deposits.

The intrusive related uranium deposits in the intrusive or anatectic rocks consist of disseminated primary, non-refractory uranium minerals dominantly uraninite, uranothorianite and/or uranothorite (IAEA, 2009). The S-type granite which is represented by Anggi and Kwatisor Granites is the target of this deposit type. The S-type granite is characterized by the presence of more aluminous minerals (biotite, muscovite, garnet, and cordierite). It has peraluminous and more alkalic to alkalic-calcalkalic and more felsic compositions. In the field, it is intimatelly associated with migmatic rocks with a regional aureole contact (Amiruddin, 2009).

The intrusive related deposits are generally low-grade (20–500 ppm), but may contain substantial resources (more than 100 kt U). One of the example is Rossing deposit, Namibia (started in production in 1991) and has totaled resources of 81.775 tU, with average uranium grade of 300 ppm, but some strong grade variation could occur up to 1%. Now it is the

largest uranium open-pit mining operation in the world (IAEA, 2009).

For the possibilities of sandstone type uranium deposit, the Triassic volcanic terrestrial Tipuma Formation is the target of uranium bearing formation (Fig. 1). Sandstone hosted uranium deposits occur in carbon and/or pyrite-bearing fluvial (less commonly marine), arkosic, medium to coarse-grained sandstones that contain, are interbedded with, and are bounded by less permeable horizons. The primary uranium minerals are predominantly pitchblende, coffinite, and to a lesser extent vanadates and phosphates. Uranium is precipitated under reducing conditions, caused by a variety of reducing agents within the sandstones (for example, carbonaceous material, sulphides, hydrocarbons and iron-magnesium minerals as chlorite). Major known sandstone-hosted uranium deposits range in age from Palaeozoic to Tertiary (IAEA, 2009). It also represents the highest reasonably assured resources in the world of recoverable below USD 260/kgU (Redbook, 2011). The major deposits in the world are Inkai, Moinkum, Akdala, Kanzhugan in Kazakhstan, and Beverley in Australia. The Beverley deposit in Australia located in Namba Formation of Lake Eyre Basin, Miocene in age, composed of siltstone, claystone, with minor sandstone, limestone and dolomite.

The carbonates are typically unfavorable host rocks for uranium because their low permeability and porosity and lack of precipitation agents such as organic matter, but such unusual geological circumstances associated with tectonic features might created traps for uranium precipitation (Bruneton, 2011). The Korem Formation in Biak represented the possibilities of uranium occurrences in carbonate rock.

The unconformity related deposits are deposits that are associated with and occur immediately below and above an unconformable contact that separates a crystalline basement (intensively altered) from overlying clastic sediments of Proterozoic age. The Precambrian or early Paleozoic metasediments of Kariem Formation which is unconformably overlain by metaigneous Awitagoh Formation and subsequent sediment of Tuaba Formation (Cloos et al, 2005 and Harahap, 2012) is the target of possible unconformity related deposit type. Granath et al (2012) also describe the pre-Paleozoic Kariem Formation which is composed by sandstone and shales. Besides outcropping in Papua, the Kariem Formation also found in wells in Arafura sea, and it lies above Awitagoh mafic volcanic.

Granath et al (2012) also highlight the relationship between South-Australia and North-Indonesia, i.e. the McArthur with Arafura basin. McArthur basin developed during Proterozoic while Arafura basin developed during Neoproterozoic to Paleozoic (Figs. 2 and 3). The basement of the Aru Ridge, which trends generally NNE-SSW from Aru Island toward Darwin may represent the continental core over which the massive supra-crustal section of the Arafura and McArthur basins was deposited. This basement may be older Proterozoic metamorphic complexes similar to the Pine Creek Inlier, or more likely they are similar in nature to late Archean inliers onshore in Australia.

The Palaeoproterozoic Pine Creek Inlier and the overlying Palaeo to Mesoproterozoic McArthur Basin in northern territory of Australia is the location of the world-class unconformity-related uranium deposits in the Alligator Rivers field, as well as the Rum Jungle and South Alligator Valley fields (Mckay and Miezites, 2001). Major mine and unworked deposit in Alligator Rivers Uranium Fields are Jabiluka, Ranger, Koongara, in Rum Jungle Uranium Fields are Embayment Area and Rum Jungle Creek South, and in South Alligator Valley are Coronation Hill, Sielsbeck, and El Sherana (Fig. 4).

Some of the geological features associated with uranium deposits in Pine Creek Inlier are intra-

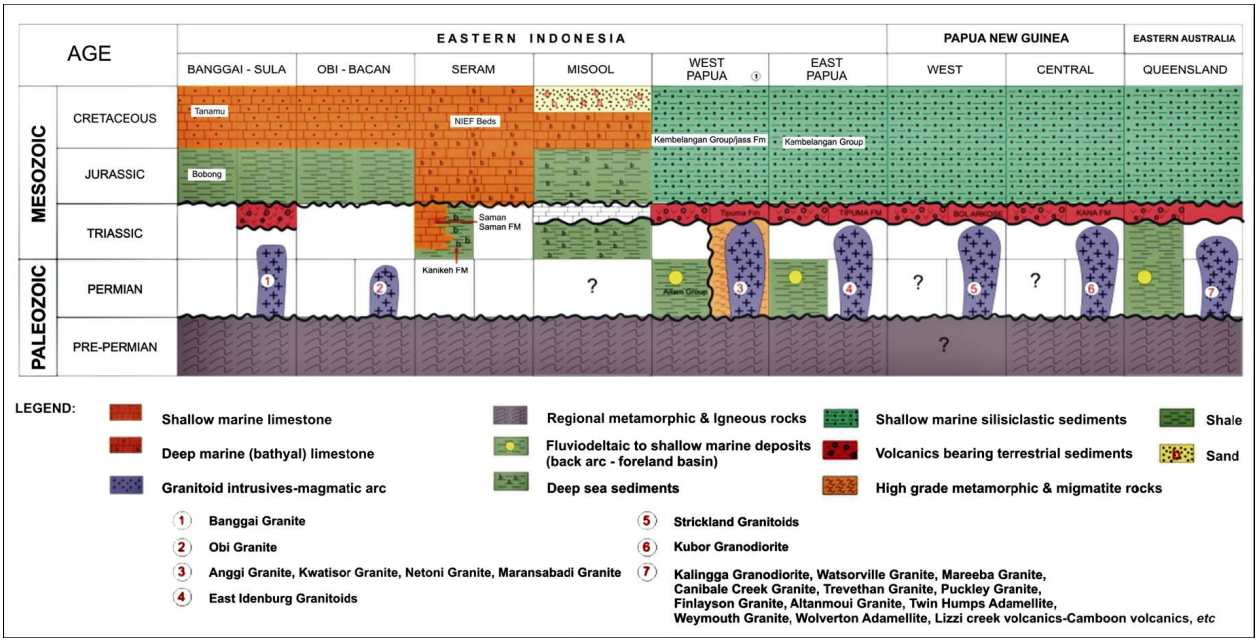

Figure 1. Simplified Late Paleozoic to Mesozoic rock units in Eastern Indonesia, Papua New Guinea, and Eastern Australia (Amiruddin, 2009)

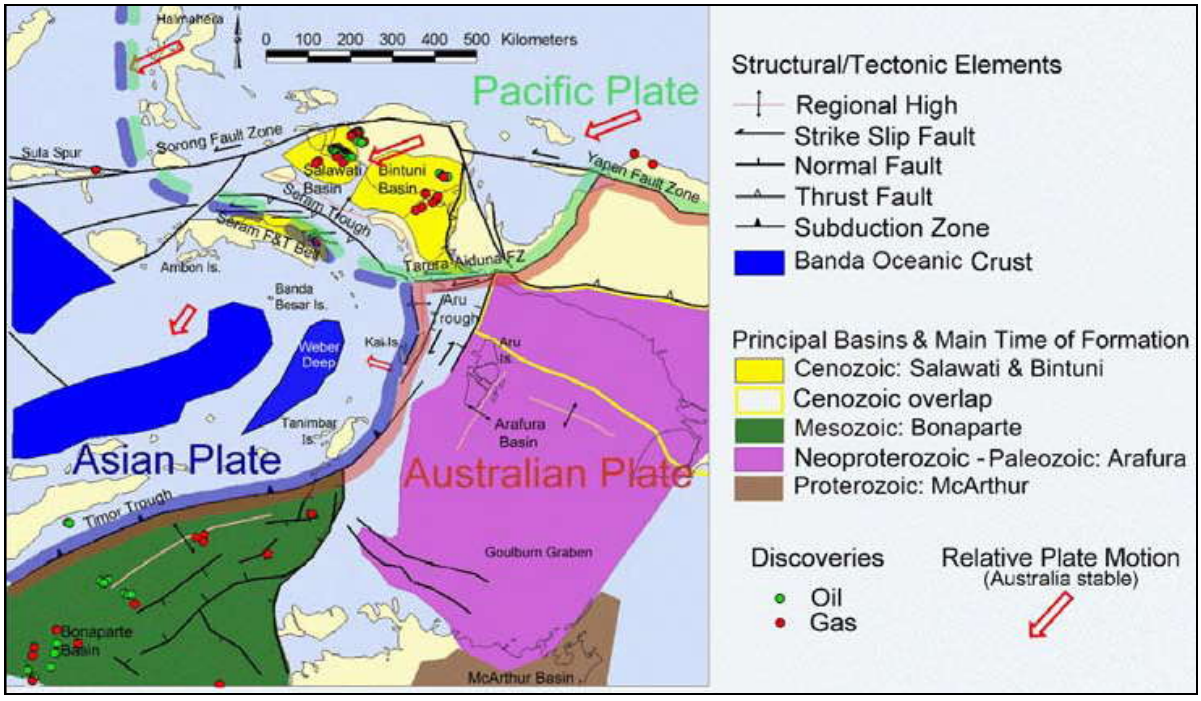

Figure 2. Tectonic element in study area (Granath et al, 2012)

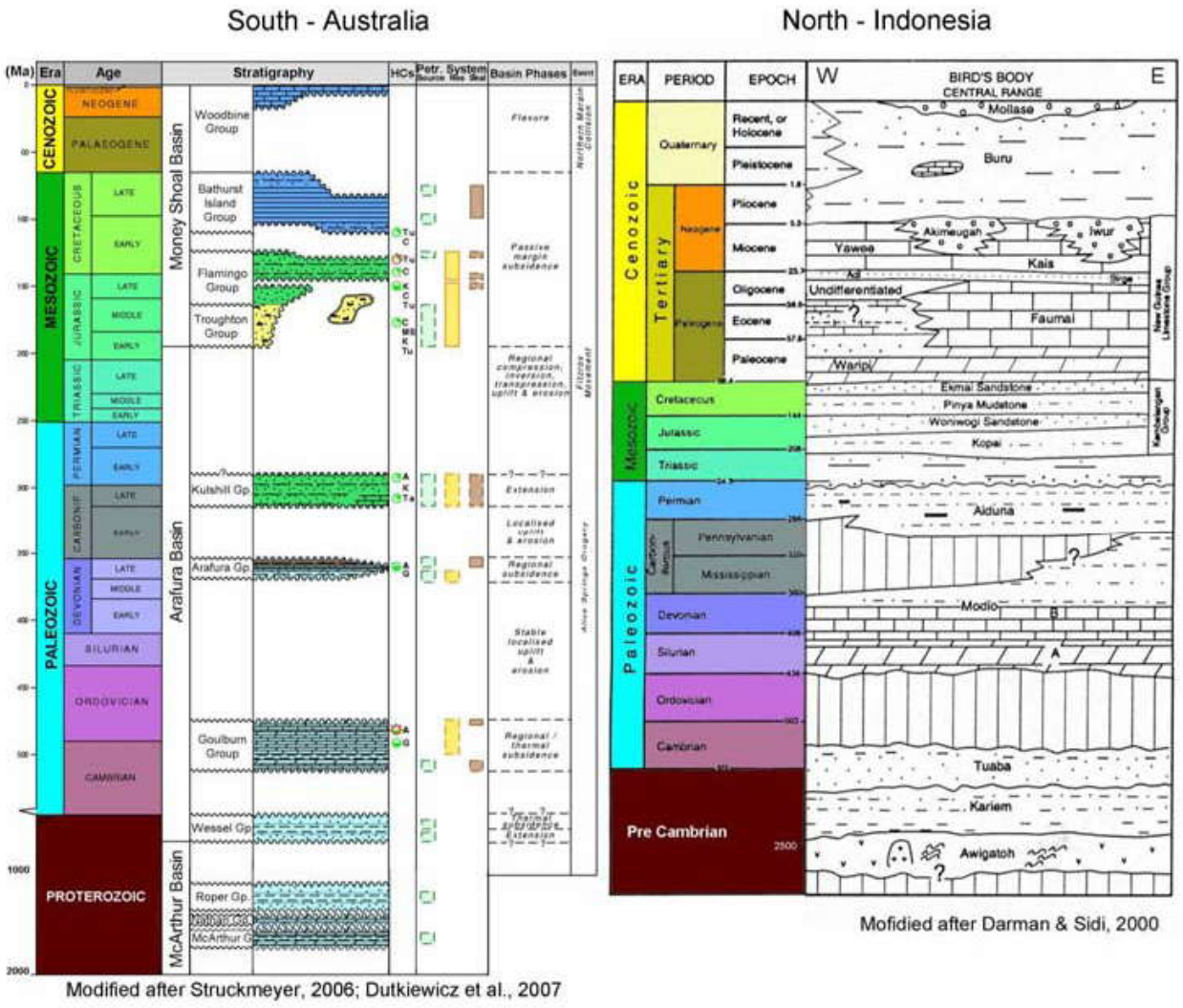

Figure 3. Generalized stratigraphy of the region (Granath et al, 2012)

continental or continental margin basins, oxidized thick cover sequence of quartz rich sandstone, the chemically reduced basement, association with Palaeoproterozoic/late Palaeoproterozoic unconformity. The source of uranium identified as Archaean and Palaeoproterozoic granite, and in several other deposits such as Jabiluka, Nabarlek and Koongarra the source of uranium also come from Palaeoproterozoic metasediments and post-unconformity highly altered volcanics (McKay, 2001).

Hills and Richards (1972), Cooper (1973) in McKay et al (2001) re-interpreted uranium and lead isotope measurements obtained by Greenhalgh and Jeffrey (1959) and found that five pitchblende samples from the El Sherana, Palette and Sleisbeck deposits indicated an age of 815–710 Ma. Another two samples from Palette suggested another mineralisation or secondary solution and re-deposition of uranium at 500 Ma. Based on this information the Kariem Formation is the best possible targets for the uranium occurrences in the unconformity-related uranium type of deposit.

GEOCHEMICAL DATA COLLECTION

Geochemical data have been collected in four interest areas, i.e. Interest Area 1 located in Arfak Mountain, Siwi Atas - Manokwari (Bird Head of Papua), Interest Area 2 located in Mimika which is represented by various rocks from Tembagapura to Timika, Interest Area 3 located in Yahukimo section taken from Nalca District - Dekai District, and Interest Area 4 located in Biak and Tual Island, West Papua (Fig. 5).

Interest Area 1

The geochemical data of Interest Area 1 of Siwi Atas - Manokwari was collected by sampling of stream sediment and heavy minerals. From earlier investigation, some favorable rocks were found at Anggi Granite in Siwi Atas. There are 18 locations of radiometric anomalies (450 cps - 2500 cps) and 13 locations of stream sediment anomalies (7,1 - 17,3 ppm) (Wahlan & Tatang, 1977). Another survey also found stream sediment anomalies (4 - 16 ppm), soil anomaly 150 ppm and rocks anomalies (200 - 500 ppm), in the same area (Hutchison, 1976).

Kemun Formation (schist, phyllite, slate, quartzite), Netoni Granite (granite, syenite) and Wariki Formation (granodiorite) were observed in Arfak Mountain. In this mountain, there are 15 locations of stream sediment anomalies (0,73 - 1,71 ppm) and 6 locations of heavy mineral anomalies (17,53 – 49,19 ppm) with rock radiometry of 70 - 390 cps (Aldan et al, 1993).

Cumin Formation (slate, schist, phyllite, silt, quartzite), was also mapped in West Nabire, together with Kuartisore granite, Tipuma Formation (sandstone, conglomerate, claystone silt) and Kembelangan Formation (silt, sandstone). Nevertheless, the radiometric anomaly was not identified, except 10 locations of stream sediment anomalies (0,04 – 12,6 ppm and 10 locations of heavy mineral anomalies (0,80 - 1509.0 ppm) (Tambunan et al., 1994).

Wandaman Formation (quarzite, schist, phyllite) was observed in East Nabire, along with Malaiurna Granite (granite), Darewo Formation (slate, phyllite, metasandstone), Otawa Diorite (granodiorite), and Befour Formation (sandstone, conglomerate and claystone). The radiometric anomaly in this area was also not identified, except 4 locations of stream sediment anomalies (0,1 - 4,22 ppm) and 14 locations of heavy mineral anomalies (0,3 – 7,52 ppm) (Tampubolon et al, 1994).

In Kwatisore Granite a stream sediment anomalies of 14 ppm were identified. In Kembelangan Formation, stream sediment anomalies of 75 ppm were identified in Eranotali. Also in Wandamen, gneiss, stream sediment anomalies of 16 ppm and heavy mineral anomalies of 150 - 370 ppm were localized (Dow et al, 1984).

The exploration results in the Interest Area 1, only found weak and limited anomalies, and they are generally associated with granitic rocks i.e. Anggi Granite, Kwatisore Granite, Netoni Granite and Malaiurna Granite. However, no anomalies were localized in the sediment and metasediment rock formations. Further detailed exploration should be conducted in the granitic rocks to optimize the possible intrusive type uranium deposit (Sumantri et al, 1995).

Interest Area 2

The geochemical data in the Interest Area 2 was collected by analysing uranium contents of some various rocks in different formations along Timika-Tembagapura road track (Fig. 6). The rock anomalies were identified in red sandstone of Tipuma Formation with the uranium grade of 32 ppm (Table 1).

The uranium deposit of sandstone type is interpreted to be present between the Tipuma Formation (Triassic - Jurassic) and Aiduna Formation of the Aifam Group (early – late Permian). The Tipuma Formation consists of mainly redbed facies rocks (lithic

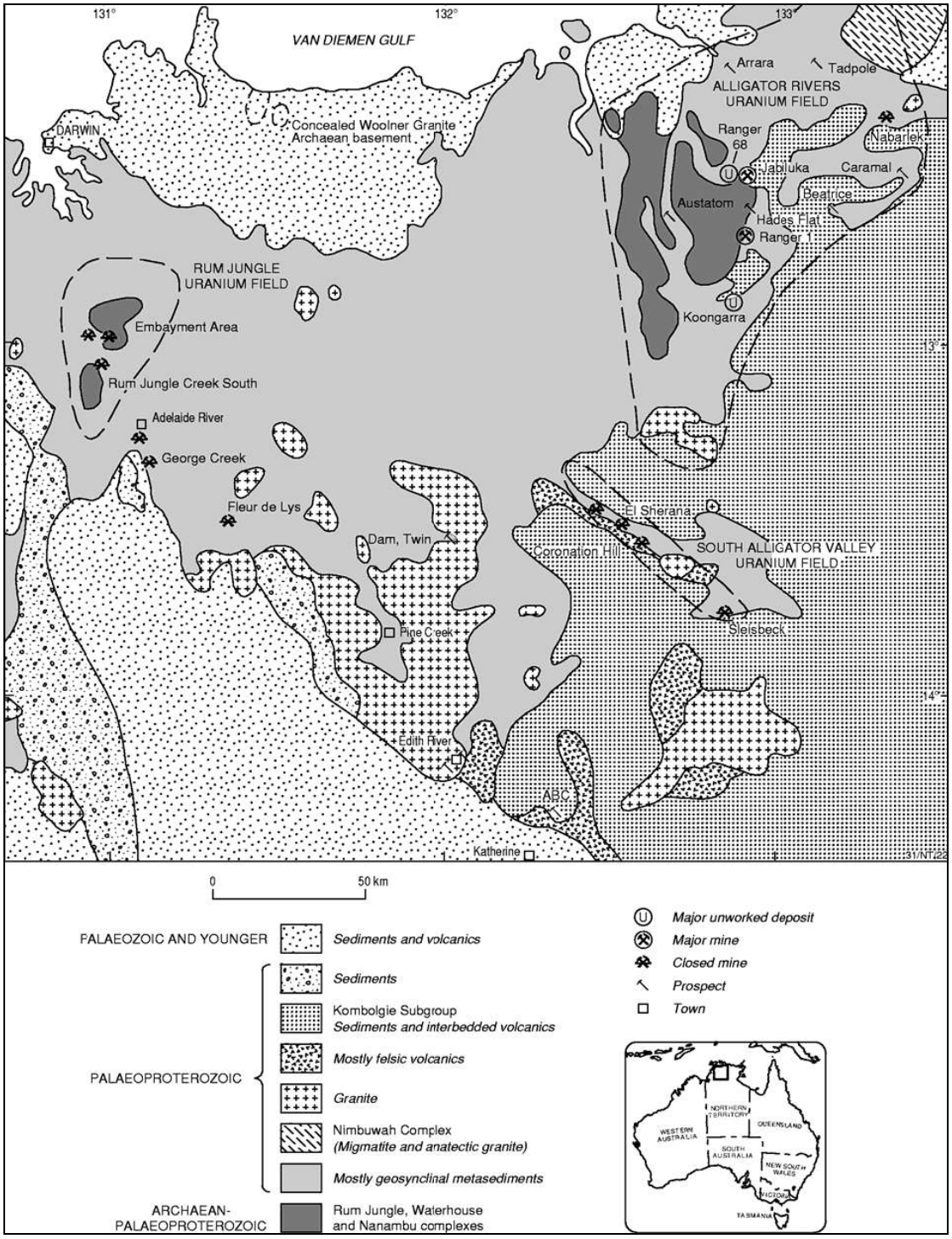

Figure 4. Generalized regional geology, Pine Creek Inlier, showing uranium fields, deposits and prospects (McKay et al, 2001)

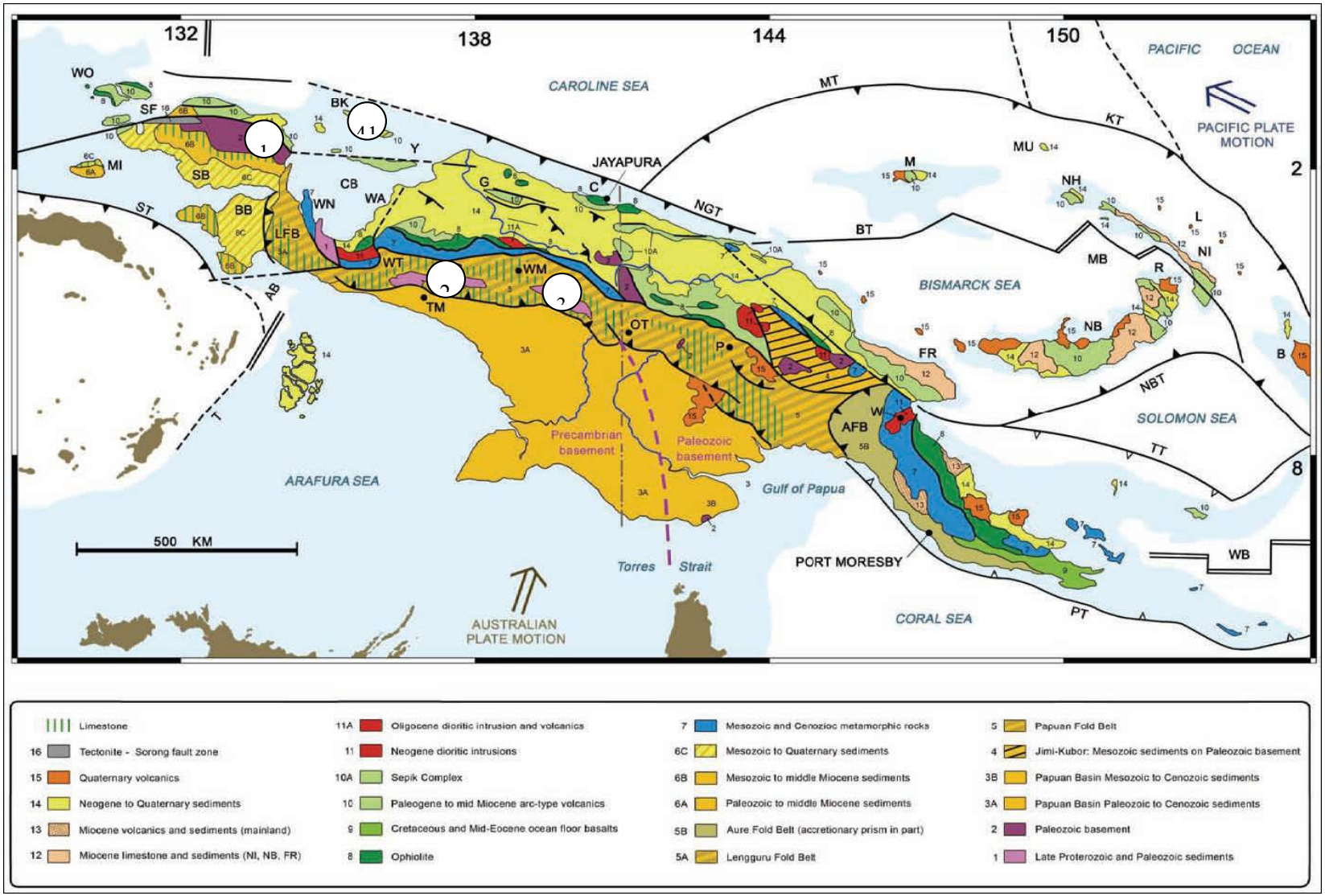

Figure 5. Generalized Geological Map and Interest Area (Modified from Davies, 2012)

sandstone, pebbly conglomerate, mudstone, arkose, tiffaceous volcano-lithic sandstone) cross bedding common, generally in fluviatil – shallow marine depositional environment. The Tipuma Formation lies unconformable under the Kopai Fm of Kembelangan Group and conformably on the Aiduna Formation.

The Aiduna Formation consists of feldspathic and micaceous lithic sandstone (lithic graywacke, shale, and siltstone; minor biocalcarenite and polymictic conglomerate; rare quartz sandstone, sandy calcarenite and coal; pyrite dissemination and nodules. Sedimentary structures were identified as crossbed, cut and fill structures, ripple marks and load casts. Based on the geological setting it is interpreted that the Tipuma Formation is re-sedimentation of Anggi Granite as source rocks of uranium (32 ppm U) with various facies as host rocks and Aiduna Formation with coal facies as uranium hot rock and barrier. The location of this setting is in Agimuga District, Mimika Regency, Papua Province.

Interest Area 3

The unconformity related type of uranium deposits is interpretated to be present in the unconformity between Paleo – Mezo Proterozoic (Awitagoh Formation and Kariem Formation). Kariem Formation consists of indurate black or dark greenish blue or grey mudstone, those are variably calcareous, carbonaceous and pyrite; indurated light greenish blue grey dolomitic mudstone and green – grey fine crystalline quarzites. The formation has been slightly metamorphosed based on its high petroleum maturity values, depositional environment of this formation is probably on deep sea under anoxic condition. The Kariem Formation has an unconformity contact with the Kembelengan Formation (Jurassic – Cretaceous). The Kembelengan Formation consists of glauconite sandstone, quart sandstone, mudstone, siltstone, claystone and shale with minor conglomerate and calcilutite with depositional environment of deep marine to gentle continental slope remote from relief landmass. This geological setting is used to interpret that the uranium deposits could have correlation with uncorformity and geological structure between the Kariem Formation (Paleo – Mezo Proterozoic) and Kembelangan Group (Jurassic – Cretaceous Age). The location of this setting is in Nalca District, Yahukimo Regency, Papua Province. Radiometric data in this area are 250 cps – 300 cps and the geochemical stream sediment data have higher concentration of U than the another place with value is around 3,84 ppm U, with data average 1,68 ppm U.

Interest Area 4

This location is located in Biak Island West Papua. Biak is composed of sedimentary and volcanic rocks. The soil sampling and analysis have been conducted for uranium content. Of 21 selected samples, four anomalies were localized in the soil with anomalous range of 22 ppm to 50 ppm U. Three anomalous uranium samples taken from the Quaternary Mokmer Formation, composed of coralline limestone and chalk. The other formation is Wainukendi Formation which is composed of crystalline limestone, marl, fossiliferus limestone and graywacke locally basaltic conglomerates lenses. There is no indication of anomaly in other formations as well as in the Eocene Auwewa Formation which composed by intermediate to mafic volcanic rocks. In this interest area, the prospective uranium bearing formations are limestone and chalk. The same condition can also be interpreted in Tual Island, West Papua.

CONCLUSION

The uranium anomalies identified which are related to sandstone hosted deposit is in the Tipuma Formation and related to the unconformity between Kariem and Kembelangan Formation even there are still

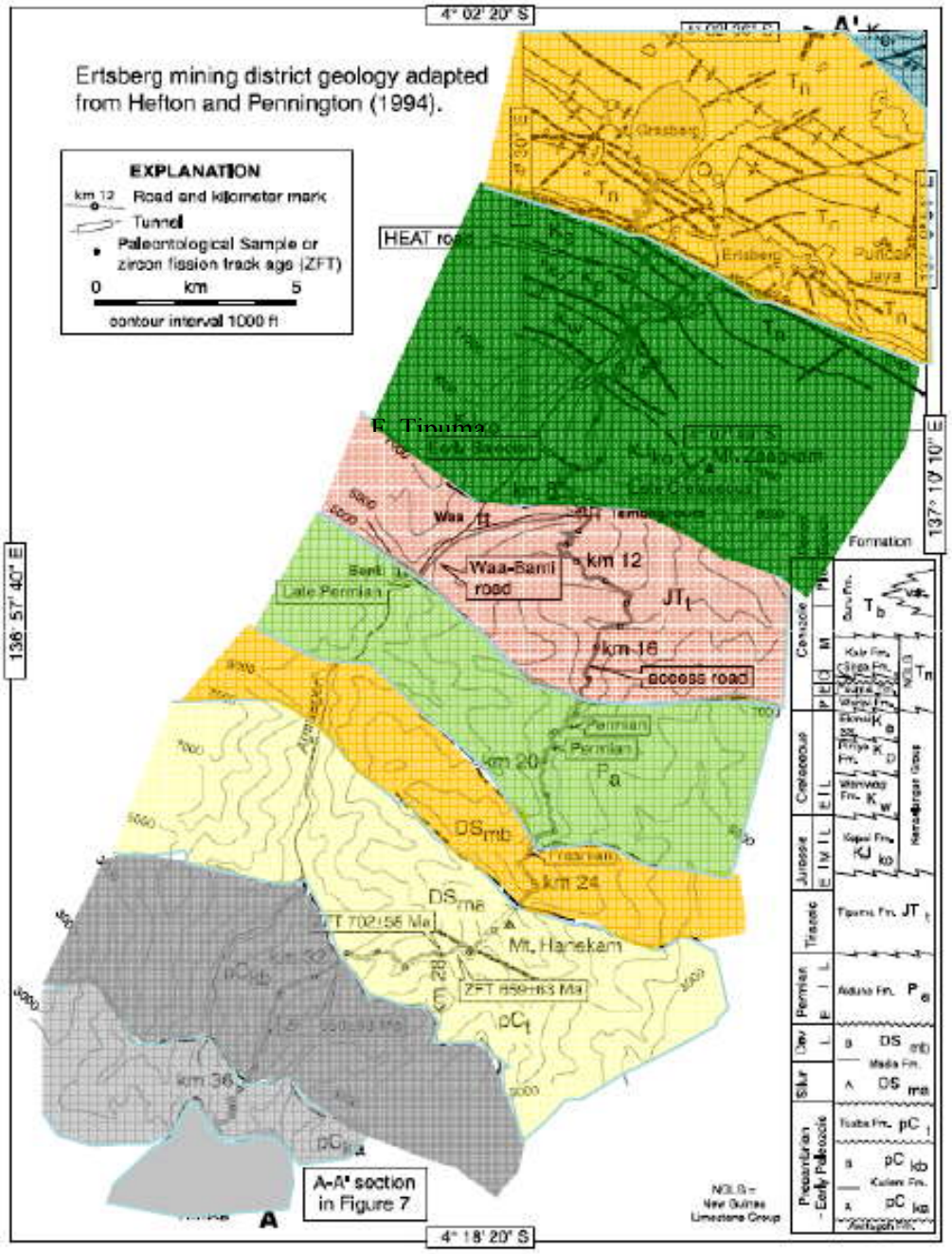

Figure 6. Lithology and stratigrafi along Timika-Tembagapura street (Soebari, 2010)

Table 1. Uranium content from various rocks in Interest Area 2

No	Location	Grade
1	Limestone (Nugini Laimestone)	9 ppm U
2	Diabasic Dyke	4 ppm U
3	Waripi Limestone	10 ppm U
4	Siltstone (F. Kembelengan)	6 ppm U
5	Red Sandstone (F. Tipuma)	32 ppm U
6	Black Shale (F. Aiduna)	5 ppm U
7	Dolomit (F. Modio)	4 ppm U
8	Sandstone (F. Tuaba)	5 ppm U
9	Shale (F. Otomona)	5 ppm U

have weakly indication or mineralization. While the carbonate hosted uranium deposits is observed in the Quaternary Mokmer Formation and Oligocene Wainukendi Formation. Further follow up exploration works are required to collect more data and to understand the geology, geochemistry, and mineralisation aspects, as well as their potential.

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