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| Research Article |

Indications of Placer Gold Deposits Based on River Sediment and Pan Concentrate Analyses in Senggi District, Keerom Regency, Papua

Raditya Atha Candela Pramulyo*, Syachrul Meizikri, Fauzi Aqilla Waskitho

Department of Geological Engineering, Faculty of Geological Engineering, Universitas Padjadjaran, 45363, Indonesia

** Correspondence: raditradit2004@gmail.com*

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Abstract: Placer gold occurrence is controlled by the interaction between geological processes, sediment transport, and depositional environments. This study assesses the indications of placer gold in the Senggi District, Keerom Regency, Papua, through integrated geological mapping, sedimentological analysis, and heavy mineral characterization. Field investigations involved structural measurements of the Miocene Makats Formation and the collection of three (n = 3) representative stream sediment grab samples (dry weights: 187.51 g, 215.65 g, and 297.70 g). Heavy mineral pan-concentrate analysis was verified under a binocular microscope with a calibrated eyepiece micrometer and micro-stylus malleability tests. A total of 21 fine-grained gold particles (0.125 mm to 0.063 mm) were physically recovered: sample H2.3 yielded 19 grains (mass-normalized abundance of 88.11 grains/kg), H2.4 yielded 2 grains (6.72 grains/kg), and H2.1 showed no gold. Sedimentological and structural results reveal that gold accumulation is highly localized, hydro-structurally trapped by sub-vertically dipping strata (up to 86°) acting as natural bedrock riffles. The probable provenance points to the upstream volcanic rocks of the Auwea Formation. While these preliminary results confirm secondary gold indications, the evidence is insufficient to define an economically significant deposit. The primary significance of this work lies in providing the first formal geological verification in Senggi and demonstrating the methodological value of integrating indigenous community panning knowledge with systematic, mass-normalized laboratory verification. This integrated workflow offers a highly reproducible, low-cost screening template for initial gold exploration in similarly data-scarce and geologically complex tropical settings globally.

Keywords: placer gold, fluvial sediment, geological survey, heavy mineral concentrate, Papua

INTRODUCTION

Senggi District and its surrounding areas, Keerom Regency, Papua Province, represent a region with geological and geomorphological characteristics that are relevant to investigating placer gold occurrence. In general, this area is characterized by active river systems, alluvial deposits, floodplains, and exposures of clastic sedimentary rocks in several parts of the river valleys. These conditions indicate the occurrence of active erosion, sediment transport, and deposition processes. Within fluvial systems, these processes play an important role in controlling the distribution of heavy minerals, including gold, because gold grains with high specific gravity tend to accumulate in areas with decreasing flow energy, such as riverbeds, point bars, river confluences, bedrock fractures, and floodplains (Khosronejad et al., 2022; Yeend & Shawe, 1989).

Placer gold deposits are secondary deposits formed through the liberation of gold grains from source rocks by weathering processes, followed by transportation and redeposition by water. In river environments, gold as a heavy mineral may undergo hydraulic sorting together with other heavy minerals, resulting in its occurrence being strongly influenced by river morphology, flow energy, sediment grain size, and the presence of natural sediment traps. Therefore, the identification of placer gold deposits requires not only information on the presence of gold grains but also an understanding of the relationship between river systems, alluvial sediment characteristics, and possible sources of gold-bearing materials (Yeend & Shawe, 1989).

The initial indication of placer gold occurrence in Senggi District was obtained from traditional gold panning activities conducted by local communities along several river channels. These activities indicate that river sediments in this area may contain gold grains, although such information remains indicative and insufficient to scientifically explain the geological conditions. In early-stage exploration activities, information derived from traditional gold panning can serve as an initial indicator; however, it requires verification through geological field observations, fluvial geomorphological analysis, sediment characterization, and pan concentrate analysis. Nzulu et al. (2021) stated that panning concentrates can be used to identify gold indicator minerals and provide preliminary information regarding the relationship between gold, heavy minerals, and their associated sediments.

Studies on alluvial gold and traditional gold panning activities are also important because many tropical regions with placer gold indications still lack adequate geological data. Gupta et al. (2024) demonstrated that small-scale alluvial gold mining activities are widely developed in tropical river environments but are often not supported by sufficient geological understanding regarding the source, distribution, and characteristics of the deposits. However, assessing the true potential of the Senggi area requires benchmarking these indications against established placer deposits in similar tropical terranes. For instance, Iglesias-Martínez et al. (2020) investigated secondary gold in the tropical Minvoul greenstone belt, reporting transported alluvial grain sizes averaging between 0.165 mm and 0.55 mm (2.6Φ to 0.85Φ). Similarly, in a comparable Indonesian fluvial setting, Ulva et al. (2022) documented localized heavy mineral accumulations in South Sulawesi, reporting alluvial gold concentrated specifically within point and channel bars with grades ranging from 94.16 to 97.86 ppm. In direct comparison, our analysis of the Senggi river sediments yielded a highly localized occurrence: sample H2.3 (215.65 g) contained 19 gold grains (17 in the mesh 120 fraction and 2 in the mesh 230 fraction), while sample H2.4 (297.70 g) contained only 2 gold grains in the mesh 120 fraction. Furthermore, the gold grains identified in our target samples were exclusively fine-grained, ranging in size from 0.125 mm to 0.063 mm. The substantially finer grain sizes and much lower, localized concentrations observed in our samples compared to regional baselines such as South Sulawesi provide necessary scientific verification of the deposit's characteristics, suggesting extensive hydraulic sorting and a significant transport distance from the primary source rock.

Regionally, Keerom Regency is part of northern Papua, which consists of Tertiary to Quaternary geological units. Based on the Geological Map of the Keerom Sheet, the research area and its surroundings are composed of alluvial deposits, volcanic mud deposits, and clastic sedimentary rocks belonging to the Makats Formation and other surrounding rock units (Koswara, 1995). The Makats Formation generally consists of sandstone, siltstone, and layered claystone, while Quaternary deposits occur as surface deposits associated with fluvial systems. These geological units play an important role in supplying sediment materials that are subsequently transported and redeposited by active river systems in the Senggi area.

Geological studies conducted in Keerom Regency, particularly within Senggi District, remain limited. Most previous investigations have focused on regional geological characteristics and mineral resource assessments in adjacent areas. Patabang et al. (2023) reported the occurrence of economically valuable limestone resources in Skanto District, Keerom Regency, indicating the presence of carbonate sedimentation and marine depositional environments within the region. The occurrence of limestone provides important information regarding the paleogeographic evolution of northern Papua and may assist in understanding the distribution of sedimentary units that extend into neighboring areas, including Senggi District.

The regional geological evolution of northern Papua has also been discussed by White et al. (2020), who suggested that areas located north of the Central Papua Mountains were dominated by deep-marine to shallow-marine depositional environments from the Late Cretaceous to the Oligocene. This interpretation is consistent with the occurrence of marine sedimentary units in the study area, particularly the Makats Formation, which consists predominantly of sandstone, siltstone, and claystone. In addition to sedimentary rocks, the regional geology also includes igneous and volcanic units represented by the Auwea Formation, composed of basaltic lava, diabase, andesitic rocks, and other volcanic products that are interpreted as fragments of former oceanic crust (Koswara, 1995).

The occurrence of placer gold in the study area may be related to the weathering and erosion of igneous or volcanic source rocks associated with the Auwea Formation. Through prolonged weathering, transportation, and sedimentary processes, resistant heavy minerals such as gold can be liberated from primary host rocks and subsequently concentrated as secondary placer deposits within fluvial environments. River systems surrounding the volcanic units, including the Senggi River and its tributaries, may therefore act as pathways for sediment transport and potential sites of gold accumulation. However, the primary source of gold mineralization within the region has not yet been identified and requires further investigation.

Previous studies on the geology of northern Papua have mainly focused on tectonic evolution, regional stratigraphy, sediment provenance, and basin development. White et al. (2020) explained that northern Papua has a complex geological history, reflected by variations in sedimentary rocks, volcanic rocks, and basin development influenced by regional tectonic dynamics. However, relying solely on these broad regional models is insufficient for early-stage mineral exploration in data-scarce environments. Therefore, this study is specifically focused on the reconnaissance of placer gold deposits and the evaluation of their probable provenance. By linking local geological conditions, river geomorphology, and alluvial sediment characteristics with pan concentrate analysis, this research tests whether the localized gold indications in the Senggi District are derived from the weathering of specific local units, such as the Auwea Formation. Ultimately, this approach not only evaluates site-specific placer potential but also establishes a probable provenance model that can refine reconnaissance exploration strategies for similar volcanic-arc terranes across northern Papua.

This research gap provides an important basis for conducting this study. This research not only aims to describe traditional gold panning activities or the geographical conditions of the area but also attempts to explain the relationship between geological conditions, fluvial system characteristics, river sediment properties, and the occurrence of gold grains in panning concentrates. Therefore, this study is expected to provide initial geological evidence of placer gold indications in Senggi District and its surrounding areas.

Based on the aforementioned background, this study was conducted to evaluate indications of placer gold in Senggi District, Keerom Regency, Papua Province, through the integration of geological field observations, fluvial geomorphological analysis, alluvial sediment descriptions, and pan concentrate analysis. The results of this study are expected to provide a scientific basis for assessing whether the occurrence of gold in the research area represents local secondary mineralization indications or indicates placer deposit potential that requires further detailed exploration.

METHOD

Study Area and Research Period

The study was conducted in Senggi District and surrounding areas, Keerom Regency, Papua Province, Indonesia. Field investigations were carried out from 1 to 5 August 2025. The field activities included geological observations, sediment sampling, documentation of lithological characteristics, and collection of pan concentrate samples from selected river deposits. Data processing and interpretation were conducted after the field campaign through geological data compilation, sediment description, grain-size analysis, and examination of pan concentrate samples.

Geological Field Observation

Field investigations were conducted along the Senggi River and several tributaries in Senggi District, Keerom Regency, Papua. Observations focused on geomorphological settings favorable for heavy mineral accumulation, including active alluvial deposits, riverbeds, riverbanks, point bars, and river confluences. At each observation point, river morphology, sediment characteristics, grain size, roundness, color, fragment composition, and the relationship between alluvial deposits and surrounding rock outcrops were documented.

Lithological observations were also carried out on sedimentary rock outcrops exposed along river channels and access roads. Rock descriptions included color, grain size, texture, sorting, packing, induration, and sedimentary structures. Strike and dip measurements were obtained from outcrops with clearly preserved bedding planes using a geological compass. Regional geological interpretation was supported by the Geological Map of the Keerom Sheet (Koswara, 1995), topographic data, remote sensing imagery, and relevant literature.

Sediment Sampling

Sediment sampling was done using a judgmental sampling design in accordance with the selected river-bar deposits from reconnaissance-stage placer exploration protocols. Sample placement targeted specific geomorphic settings favorable for heavy mineral concentration, particularly river bars and low-energy fluvial environments. Three representative samples, designated H2.1, H2.3, and H2.4, were selected for further analysis. Sample H2.1 (187.51 g) was collected at 3°22'49.8"S and 140°45'33"E, sample H2.3 (215.65 g) at 3°22'36.2"S and 140°45'19.2"E, and sample H2.4 (297.70 g) at 3°22'35.5"S and 140°45'23.1"E. Sampling coordinates and sample weights were recorded to ensure traceability and reproducibility. Given the collection of only three samples across the survey area, this dataset explicitly lacks the statistical power required to model spatial distribution patterns or assert localized occurrences.

Grain-Size Analysis

Sediment samples were air-dried prior to grain-size analysis. The dried samples were separated using a stack of standard testing sieves conforming to ASTM E11 specifications. The sieving process utilized mesh numbers with metric equivalents corresponding to the Udden-Wentworth classification scale: 5 (4.00 mm), 10 (2.00 mm), 18 (1.00 mm), 35 (0.500 mm), 60 (0.250 mm), 120 (0.125 mm), and 230 (0.063 mm) with the remaining finer material (< 0.063 mm) collected in the pan fraction. Each fraction was weighed to determine the percentage distribution of grain sizes within each sample. Grain-size characteristics were used to evaluate depositional energy and sediment sorting within the fluvial system.

Pan Concentrate Analysis

Heavy mineral concentrates were obtained through conventional panning based on differences in specific gravity between light and heavy minerals. During the concentration process, low-density particles were removed while heavy minerals remained in the concentrate. The concentrates were subsequently examined under a binocular microscope to identify the occurrence of gold grains, with particular attention given to the No. 120 (0.125 mm) and No. 230 (0.063 mm) fractions, which are commonly associated with fine-grained gold particles. To rule out potential misidentification of weathered biotite mica, chalcopyrite, or fine-grained pyrite, confirmatory physical diagnostic testing was performed under the microscope on a representative subset of the suspected gold grains. Specifically, a micro-stylus malleability test was conducted by applying mechanical pressure using a fine steel needle. Gold grains exhibited characteristic high malleability and ductile deformation (denting and flattening without shattering), which successfully distinguished them from brittle minerals such as pyrite (which fractured cleanly) and weathered biotite (which exhibited micaceous exfoliation). Given the reconnaissance nature of this study, this classical physical verification protocol is considered robust and sufficient for preliminary exploration stages, while more advanced chemical microanalyses (such as SEM-EDS or EPMA) are noted as recommended steps for subsequent detailed resource evaluation phases. The parameters recorded included the presence or absence of gold grains, grain abundance, particle size, and their distribution within each sample.

Data Interpretation

The placer gold potential was interpreted by integrating geological observations, sediment characteristics, grain-size distributions, and pan concentrate results. Gold occurrence was evaluated based on the abundance and size of gold grains, sampling locations, and their relationship with fluvial geomorphological settings. Placer gold occurrence was considered indicated when gold grains were identified in concentrate samples. However, because the study was conducted at the reconnaissance stage, interpretations were limited to preliminary geological indications and did not include grade estimation, resource evaluation, or economic assessment.

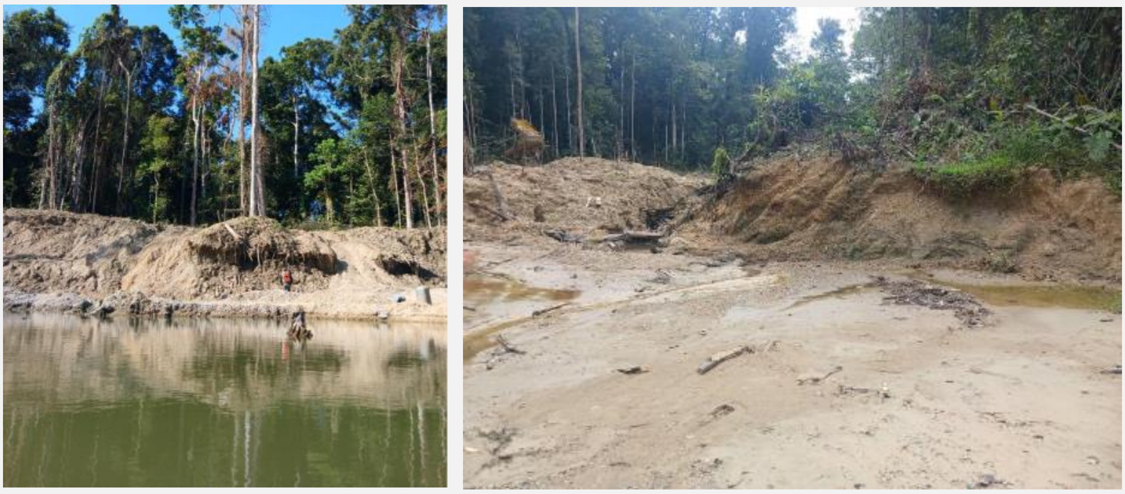
RESULTS & DISCUSSION

Local Geological Conditions

The geological setting of the study area is dominated by two lithological units: river or alluvial deposits consisting of sediments ranging in size from clay to pebble, and clastic sedimentary rocks composed of sandstone and claystone. These two units are widely distributed along the Senggi River and its tributaries, as well as within forested areas that serve as access routes.

River Deposits/Alluvium

These deposits are distributed along the Senggi River and other rivers flowing into the Senggi River. They consist of various sediment sizes, ranging from coarse pebble-sized sediments to fine sediments such as clay. Most deposits exhibit similar characteristics, with yellowish-brown to whitish-brown grains and subrounded to angular grain shapes. Sediment fragments consist of siliciclastic materials, crystals, and igneous rocks with poor sorting and varying compositions at each observation station. In addition, these river deposits are also found around rock outcrops.



(a) (b)

Figure 1. River deposits in the study area. (a) Riverbank consisting of sediment and soil deposits near the Senggi River. (b) Sediment deposits within a dry river channel located adjacent to a rock outcrop).

Clastic Sedimentary Rocks

Clastic sedimentary rocks were encountered at several observation stations, generally exposed near river channels and consisting of sandstone and claystone. Most of these sedimentary rocks exhibit bedding orientations (strike and dip) in certain directions, indicating the continuity of the sedimentary units.

In general, the sandstone is characterized by dark gray to brownish color, fine grain size, subrounded grains, good sorting, closed packing, and brittle properties. The claystone is characterized by a dark gray to greenish color, clay-sized particles, and brittle properties.

Figure 2. Sedimentary rock outcrop consisting of interbedded sandstone and claystone at observation station STD3.6.

Figure 3. Sedimentary rock exposure on the riverbed, showing dark gray fine-grained sandstone at observation station STD2.2.

In addition to physical descriptions of the rocks, bedding orientation data were collected from outcrops displaying well-preserved bedding. Outcrops lacking clear bedding or having indistinct bedding orientations were not measured.

Table 1. Strike and Dip Measurements of Sedimentary Rocks in the Study Area

Station Code	Bedding Orientation
STD2.1	N 170° E / 21°
STD2.2	N 31° E / 26°
STD2.4	N 146° E / 86°
STD3.3	N 123° E / 21°
STD3.5	N 170° E / 47°
STD3.6	N 151° E / 21°
STD3.7	N 31° E / 17°

From the two lithological units identified in the study area, no rocks exhibiting physical characteristics indicative of mineralization, magmatic intrusion, or vein formation were observed. Therefore, the rocks encountered in the field are unlikely to represent the source rocks of gold mineralization. The gold deposits present in the study area may have originated from source rocks located outside the study area and were subsequently transported and redeposited around the Senggi River together with other sediments.

Gold grains are expected to accumulate along river channels where sediments are transported and subsequently deposited in areas of low transport energy, such as river bends or point bars. Sampling of river or alluvial deposits was conducted to identify the occurrence of placer gold.

River Sediment Characteristics

Grain-size analysis results indicate that river sediments are dominated by sand- to gravel-sized fractions. Sample H2.1 shows the highest proportion at mesh 10 (29.71%), followed by mesh 35 (23.59%). Sample H2.3 is dominated by mesh 18 (33.32%) and mesh 5 (27.19%). Sample H2.4 is dominated by mesh 18 (31.36%) and mesh 5 (21.65%).

The predominance of coarse sand to fine gravel fractions indicates that sediments in the study area were deposited by a river system with sufficient energy to transport relatively coarse materials. However, fine fractions remain important because gold grains identified in this study were found within mesh 120 and mesh 230 fractions. This indicates that gold transported by the river system occurs as fine particles.

Sediment characteristics consisting of mixed rock fragments, quartz, and brownish oxide minerals suggest that the sediments originated from the erosion of various rock types in the upstream area or surrounding drainage basin. The reddish-brown coloration observed in some samples may indicate the presence of iron oxides, which are commonly associated with heavy mineral concentrates and weathering products.

Pan Concentrate Analysis Results

Pan concentrate analysis results indicate that gold occurrence is not uniformly distributed among all samples. To ensure a scientifically meaningful comparison, raw grain counts were normalized against the initial dry sample masses (H2.1: 187.51 g, H2.3: 215.65 g, and H2.4: 297.70 g) to calculate the normalized gold grain abundance (expressed as grains per kilogram of dry sediment, grains/kg). No gold grains were observed in sample H2.1 (0 grains/kg). In sample H2.3, a total of 19 gold grains were recovered from the entire panned heavy mineral concentrate, yielding a normalized abundance of 88.11 grains/kg; this comprises 17 grains in the No. 120 (0.125 mm) fraction (78.83 grains/kg) and 2 grains in the No. 230 (0.063 mm) fraction (9.27 grains/kg). In sample H2.4, a total of 2 gold grains were identified within the No. 120 (0.125 mm) fraction, corresponding to a normalized abundance of 6.72 grains/kg, with no gold observed in other fractions. Since manual panning was utilized, the recovery efficiency remains unquantified, and these normalized values represent minimum extractable abundances rather than absolute gold grade. Nonetheless, the entire panned heavy-mineral concentrate obtained from each sample was systematically examined under the binocular microscope. The identified gold grains are fine-grained, ranging from 0.125 mm to 0.063 mm in size. To precisely characterize their dimensions, all 21 identified gold grains (19 from sample H2.3 and 2 from sample H2.4) were individually measured under the binocular microscope using a calibrated eyepiece micrometer (reticle). The maximum length (long axis) and width (intermediate axis) of each of the 21 grains were recorded, confirming that all recovered particles fall within the very fine sand size classification (No. 120/0.125 mm and No. 230/0.063 mm fractions). These fine sizes and the abraded, subrounded-to-rounded morphologies observed indicate that the gold particles have undergone significant hydraulic transport and mechanical abrasion within the fluvial system. The limited number of gold grains and their uneven distribution suggest that gold occurrence in the study area remains indicative and does not demonstrate strong continuity. The most significant gold occurrence was observed in sample H2.3, indicating that this location provides depositional conditions more favorable for heavy mineral accumulation than the other locations. However, because the number of gold grains is still low and gold was only identified in specific fractions, these results are insufficient to classify the study area as containing economically viable placer gold deposits.

Interpretation of Placer Gold Potential

The occurrence of fine gold grains in pan concentrate samples indicates that the river system in the study area transports secondary gold-bearing material. Geologically, this supports the interpretation that gold supply originates from upstream areas or from source materials located outside the immediate observation area. However, since no primary gold-bearing rocks were identified near the survey area, the source of gold cannot yet be confirmed.

Gold concentration in the study area is likely controlled by hydraulic sorting processes within the fluvial system. As a heavy mineral, gold tends to be trapped in areas where flow energy decreases, whereas lighter materials continue to be transported. Locations such as point bars, riverbeds, and active alluvial deposits provide favorable environments for localized gold accumulation.

Nevertheless, the results indicate that gold grains are very limited in number and unevenly distributed. Sample H2.1 contains no observable gold, whereas H2.3 and H2.4 contain only small amounts of gold. To scientifically ground this classification, these findings must be evaluated against established placer exploration criteria in geological literature. In exploration geology, a 'reconnaissance-stage indication' is characterized by localized, isolated occurrences in small-volume grab samples (yielding low grain counts) without defined volumetric or three-dimensional areal continuity. In contrast, an 'economically significant placer deposit' in New Guinea regional frameworks requires systematic bulk sampling (minimum 20 kg dry weight per sample) to define a continuous grade exceeding the economic threshold of 500 mg/m^3 for manual alluvial operations or 250 mg/m^3 for mechanized exploitation. Panning small-mass grab samples (dry weight under 300 g) is highly susceptible to the nugget effect and is classified by the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) guidelines as a semi-quantitative tracing tool restricted to reconnaissance-stage anomalies. Due to the absence of bulk volumetric measurements, low grain counts (2 to 19 grains), and the lack of demonstrated continuity between sampling stations, the study area is more appropriately classified as an area with indications of placer gold rather than as a proven economic placer deposit.

Implications for Further Exploration

The results suggest that further exploration should be directed upstream to identify the source of gold-bearing materials. In addition, sampling should target subsurface deposits, particularly older point bars, floodplains, and sediments buried beneath younger deposits. Subsurface deposits potentially contain more stable concentrations of heavy minerals than surface sediments that are still subject to active erosion and transportation.

Further laboratory investigations should also include geochemical analysis, heavy mineral analysis, and larger-volume sampling. Such approaches would improve the understanding of the relationships among gold grains, indicator minerals, sediment characteristics, and potential source rocks.

CONCLUSION

The geological setting of the Senggi District and surrounding areas is characterized by active alluvial deposits and clastic sedimentary rocks associated with the fluvial system. River geomorphology, particularly the presence of point bars, alluvial deposits, and low-energy flow zones, provides favorable conditions for the accumulation of heavy minerals.

Pan concentrate analysis revealed the occurrence of fine gold grains ranging from 0.125 mm to 0.063 mm in size. Gold grains were identified in samples H2.3 and H2.4, whereas no observable gold grains were found in sample H2.1, indicating that gold occurrence within the surface alluvial deposits is localized and unevenly distributed.

The absence of primary gold-bearing rocks in the vicinity of the observation area suggests that the identified gold grains represent secondary gold transported by the fluvial system from upstream areas or from source rocks located outside the direct survey area. Given the exclusively fine grain sizes and localized distribution of the identified gold grains, coupled with the regional geological framework, the probable provenance of this secondary gold points to the weathering and hydraulic transport of materials from upstream volcanic units, such as the Auwea Formation. Therefore, the study area can be classified as having indications of placer gold occurrence, although the currently available data are insufficient to classify it as an economically viable placer deposit. These findings provide preliminary geological evidence for placer gold occurrence in the Senggi District and may serve as a basis for further exploration. On a broader methodological level, this study demonstrates the strategic value of integrating local community panning knowledge with systematic, laboratory-based pan-concentrate verification as an efficient, low-cost reconnaissance workflow. Such an integrated approach provides a highly reproducible screening template for initial gold exploration in similarly data-scarce and geologically complex tropical settings globally, preventing the premature overstatement of economic potential while effectively identifying key target zones for detailed subsurface follow-up. Future investigations should focus on upstream source tracing, subsurface sampling, and detailed geochemical and heavy mineral analyses to improve the understanding of gold distribution and potential source rocks. Furthermore, this study demonstrates the efficacy of integrating traditional panning as an indicator process with sedimentological verification in data-scarce environments. This methodological approach establishes a baseline for early-stage exploration and prevents economic classification within the fluvial systems.

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