Solifluction gold placers of Mongolia

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ABSTRACT

Gold placers are widespread in Mongolia, and most have been considered to be gold-bearing river alluvials. However this paper demonstrates the presence of many valley-floor gold placers that have been deposited in a non-fluviatile environment and have not undergone water-borne transport. The placers lack the expected fabrics of fluvial deposits – rounded clasts, imbricated clasts, cross-stratification, sorting and channel geometry – and are redescribed as colluvial material, considered to have moved as a water-laden slurry downslope. The term 'solifluction placers' is merited. The solifluction placers are readily mistaken with fluvial placers due to their prevalence on valley-floors, but are easily distinguished due to the clasts being ill-sorted, angular to subangular, absence of cross-bedding and occasional presence of signs of relic primary bedding fabrics of the local bedrock. The solifluction placers tend to have blurred contacts with the underlying bedrock. Solifluction placers are the only, or dominant, sediment on many valley floors. The paper summarises the results of extensive pitting in the Sergelen Goldfield, along transects across the solifluction placers, and field examination of 10 active placer gold mines in the Sergelen Goldfield. Solifluction placers are thought to be widespread in the Forest-Steppe Transition Zone and in the Steppe Zone where extremely cold winters and semi-arid conditions favour solifluction and suppress surface water flow. The paper contrasts the solifluction placers of the Sergelen Goldfield with the fluvial-dominated placers of the more important Zaamar Goldfield deposited by the Tuul river. Attention is drawn to the mass-downwasting of terraces and solifluction lobes from the valley sides at Zaamar, creating complicated vertical and lateral sequences. The Sergelen Goldfield is devoid of significant surface streams and thus is a 'text-book' example of a solifluction placer province, without the complications of remobilising of fluvial terraces and interdigitation of solifluction and fluvial deposits.

Fig.1: *Solifluction placer exposed in the working face in of the Elst Mine in the Sergelen Goldfield. The view is up-valley, to the north-east. Note the partial overturning of relict bedding in the weathered broken bedrock, indicating substantial creep from the valley side on the left (north-west).*

Introduction

Placer gold deposits are widespread in Mongolia, and have traditionally been interpreted as being the product of river and stream processes. This paper sets out to demonstrate that, in many cases, this assumption is invalid and that many gold placers do not owe their origin to river and stream processes.

The study area is the Sergelen Goldfield is the nearest gold mining area to Ulaanbaatar. The area is south-east of the capital city, south of Bogd Mountain. The goldfield is entirely within the district of Sergelen Soum in Tov Aimag ('central province").

Considerable exploration had been undertaken in the soviet era for placer gold (references), thus allowing very fast start-up of gold mines soon after private mining was permitted again in Mongolia after the change from the command economy. This was boosted by the 'Gold Project' of the Government of Mongolia, which liberated the issuing of Exploration Licenses and Mining Licenses and by the stimulus of the introduction of the new Minerals Law of Mongolia.

General Description of the Area

Landform and Climate

The landforms of the Sergelen Golfield are dominated by gently rolling treeless steppe grasslands. The hills are generally smoothly rounded with scattered small rock outcrops in the grassy steppe. Hill slopes are rarely more than a few degrees, and the typical local amplitude between valleys and hills is less than 200 metres. The abundance of active and inactive marmot burrows and the rubble excavated therefrom indicates that weathered bedrock is at shallow depth across the hills and valley sides. Small crags of bedrock are occasionally seen on the higher ground, due to resistant chert, quartz and harder siltstones.

Valleys are typically flat floored and treeless. Evidence of permafrost ice-wedge polygons is apparent on air photographs on some valley floors for restricted areas but is difficult to detect in the field.

Soils and Vegetation

A feature of the soils in the Sergelen Goldfield is the ubiquitous presence of a hard coating of whitish carbonate minerals ($CaCO_3$) on clasts in at least some horizons in the soil profiles. This is indicative of upward capilliary movement of groundwater above the normal water-table and precipitating carbonates when the groundwater evaporated before it reached the ground surface. In many instances, the whitish coatings are confined to the undersides of the clasts, indicating no rotational disturbance since the chemical precipitation had occurred. The precipitated carbonate is not sufficient to cement together the clasts to form a coglomerate or breccia, but is enough to ensure the calcareous nature of the vegetation.

The vegetation consists of dry steppe grasslands, dominated by herbs and lichens as well as grasses. Grazing by marmots and small rodents is locally intense, with only scarce visits by herds of gazelle.

The valley floors are often damp enough to support seasonally lush grassland but springs are infrequent and peat areas are rather rare.

The grasslands are heavily grazed by substantial flocks of cashmere goats and sheep, and by herds of horses and cattle.

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Geological Setting

The underlying solid rocks of the Sergelen Goldfield are a monotonous serquence of regionally-metamorphosed sediments of supposed late Precambrian (Ripean) age, dominated by low-grade dark grey phllytic slates and argillaceous dark grey siltstones, exhibiting marked high-angle cleavage deformation. The sequence of metasediments also includes occasional, but locally thick, beds of red jasperoidal chert. Cutting the sequence are occasional thin milky quartz-dominated veins and thin igneous dykes that merit further study. The metasediments are part of the Khentii Fold Belt, and the local strike of the bedding and cleavage conform closely to the dominant regional NE-SW structural trend. Several open folds trending ENE-WSW are traceable, with some difficulty, across the Sergelen Goldfield.

To the south is a small intrusion of weathered coarse granite, locally giving a weakly tor-dominated landscape but otherwise with smoothly rounded hills albeit with some granite boulder fields. The expected hornfels thermal metamorphic aureole has not been convincingly demonstrated.

No plutons occur inside the Sergelen Goldfield, but elsewhere the metasediments of the Khentii Fold Belt are intruded by large granitic plutons, such as: the Bogd Granite of Bogd Mountain to the immediate NW of the Sergelen Goldfield; the famous Terelj Granite of the Terelj National Park to the NNE and the tin-tantalite-tungsten-REE granites of the Janchivlan Massif to the ENE (Tumenbayar, Batbayar and Grayson 2000).

Faulting in the Sergelen Goldfield is not dominated by any single large fracture, but by a network of small faults that criss-cross the entire area. These are visible on old vertical black and white air photographs flown. Faults control the orientation of most of the valleys and follow the valley floors, causing the valleys to be linear and straight. The floors of the valleys are thus believed to be underlain by fissured and broken fault breccia, although this has been rarely been seen. Consequently considerable volumes of ground-water can be found by drilling and this water is essential for placer mining. Surface streams are very rare, prone to dry up and tend to consist of a string of weak springs and often flow for only a few tens of metres before disappearing again.

Antiquity of the Present Landscape

Almost all the valleys are devoid of “youthful” features, having gentle sides and smooth gentle long profiles. However this does not necessarily indicate an ancient origin, as the harshly continental semi-arid climate causes the main geomorphological agent to be downslope mass-movement, a relentless process that is capable of obliterating most other surface features in the space of perhaps only a few thousand years.

Supporting evidence for the antiquity of the valleys is from the presence of a “false bottom” beneath the floor of several of the larger valleys, whereby instead of the expected bedrock beneath the placer, there is a bed of dull brown sticky clay. Beneath this false bottom is a second layer of sediments often with a second gold placer layer before the real bedrock is reached. The origin of the clay layer is not known, but its presence, and that of a double placer, suggests that at least some of the valleys have had a long history of development. Mongolian workers consider the clay layer to be early Quaternary or Neogene in age, although concrete evidence is lacking. If correct, then the erosion of the valleys had been essentially completed about a million years ago. More investigation is required, but it is tentatively suggested that the modern landscape is essentially a “fossil landscape” little-changed in physical form. If correct, then the biggest physical impact over the last million years has been placer gold mining in the last 10 years.

Occasionally, weak fault scarps are apparent and can be traced for 50 to 100 metres or so, suggesting that some of the valley-trending faults have been active in historical times, but not enough to alter the geomorphology to more than a minor extent.

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Description of the Placers & Overburden

The placers are valley-floor deposits. Only in a few rare instances have economic grades been found away from the valley floors. Overburden is thin, generally only 1-3m thick.

The northern part of the Sergelen Goldfield is subeconomic, even though "up-valley" of active and profitable placer mines. This was discovered in spring 1998, when Eco-Minex International Co. Ltd. (EMI) began 'wildcat' exploration of Exporation License 1049X, on the northern edge of the Sergelen Goldfield. The first task was to dig120 widely-scattered shallow prospecting pits averaging only 50cm deep, gold was detected in an impressive 20 holes (24%). Gold can therefore be said to be exceptionally widespread and shallow, at least in the northern part of the Sergelen Goldfield. This was confirmed by further 'wildcat' shallow prospect pitting by EMI in spring 19?? In a second area, Exploration License X-1???, with a further ?? shallow pits detecting gold in ?? instances (xx%).

On this basis, a modest Exploration Programme of pitting was conducted with pits dug 5m deep, and spaced 20m apart in transects across the North Yellow Valley and South Yellow Valley in 1049X, the transect lines at the customary spacing of 1,600m, then 800m, then 400m, then 200m and - if justified - 100m.

Results were complex, with the valley floor placers very long (3km plus) but narrow (rarely more than 20m wide), and often split into branches less than 10m wide. Even with gold grades occasionally as high as 500mg/m^3 and often with zero overburden, the placers were considered to be too complex to for conventional mining methods. The absence of visible marker horizons demarcating the top and bottom of the placers (often only 20cm to 1m thick) was a cause for concern. In contrast the technological challenge of the fine gold (30 to 50 microns) was solved by careful panning, cross-checked with a 3-inch KNELSON™ centrifugal concentrator provided by Ochir Leasing Co. Ltd.

The following description of the overburden and placers is based upon EMI's extensive pitting in the northern part of the Sergelen Goldfield.

The sedimentary sequence is summarised below:

TYPICAL CROSS-SECTION Northern part of Sergelen Goldfield				Geological Interpretation
Top Soil		Top soil with silt & clay	Nil – 0.5m	Recent soil cover
Overburden		Rounded pebbly gravel	Nil – 0.2m	Recent intermittent Stream Deposit
Overburden		Subangular coarse gravels & interstitial silt, sand and clay. Clasts with dropstone carbonate coatings.	0.1m – 2.5m	Solifluction Downslope Deposit
Placer		As above, but terminal curvature and relict bedding	0.05m–1.5m	Solifluction Downslope Deposit trapping gold
Placer		Broken bedrock	0.2m – 5.0m	Broken bedrock trapping gold
Bedrock		Metamorphic slate, sultstone	0.3m	Bedrock with placer gold content in cleavage

Pitting and careful recording of the pits revealed the solifluction nature of the placers in the North Yellow Valley and the South Yellow Valley, and in trial pits in several other valleys in 1049-X. Without exception, no evidence of water-borne deposition was found. Without exception, the placers and the bounding units consist of highly angular clasts with relatively sharp corners; chaotic mixtures of clast sizes; widespread clay matrix; no imbrication structures, no water-sorted intervals, and with many clasts at steep angles as well as gentle. No difference was apparent between the valley floors and the lower slopes of the valley sides.

Rounded clasts, size-sorting and imbrication were only apparent with clasts associated intimately with the 'misfit' streams, and rarely constituted a unit more than a mere 5cm thick. In all cases, the fluvial sediment was at the top of the sequence, effectively at the soil/air interface, suggesting that seasonal fluvial action was only recently significant, albeit weak. This need not be due to increased precipitation, but might be due to increased aridity causing shrinkage of organic peaty soils which may formerly acted as a water-absorbent layer protecting the underlying sediment from scour.

Some pits encountered shallow water table (2 to 5 metres deep) and down-valley (south) some pits encountered frozen ground.

Placers & Overburden in Active Mines

The following description of the overburden and placers is based upon EMI's extensive inspection of the working faces of all the placer gold mines in the Sergelen Golfield, to the south of the area described above. Unlike the northern subeconomic part, the southern and central part of the Sergelen Goldfield sustains 10 placer gold mines, the placers having better grades (0.4 to 1.5 gm/m^3), greater width (50-150m) and are more easily traceable along the valley floors. Being down-valley, the valleys tend to be wider, and groundwater is more prevalent.

Fieldwork demonstrated that all the working mines are in solifluction placers as described above. As in the EMI trial pits, the shattered underlying phyllitic slates were also part of the economic placer, due to fine gold pervading into the weakened open cleavage and cross-joints.

Unequivocal evidence of solifluction origin was found in 1998 in one face of an active mine which had sliced a transect across an entire valley floor. Inspection proved 0.5m overburden of waterlogged peaty soils with rounded fluvial imbricate clasts, resting on 3m solifluction placer grading downwards into shattered bedrock of cleaved phyllitic slate. The placer clasts were of the usual angular nature but many were in rough alignment preserving the original bedding forms, yet generally overturned and distorted. The outcrop showed several 'flip-overs' not present in the underlying bedrock, due to mass movement laterally from the western gentle (5 degree) slope of the valley side. This had been sufficient to transport relict bedding to the opposing (east) side of the valley floor. Clay matrix dйcollement shear planes were apparent which facilitated movement.

Fig.2: *Elst Gold Mine in the Sergelen Goldfield. The mounds are of bulldozed thin overburden and topsoil, and the 'cliff' is the placer margin. The floor of the excavation is of shattered slatey bedrock. The small digging is of an illegal miner seeking gold in the shattered bedrock.*

Deposition of the Gold in the Solifluction Placers

The placers are deposited by solifluction, but is their gold content also deposited by the same means? Support includes discovery by EMI of hard-rock gold in 1049X in jasperoid cherts, and the potential source rocks presented by untested numerous quartz veins. However, remote sensing and ground truthing indicates three additional factors complicate the issue:

Marmot Burrow Systems

The prolific nature of bioturbation by Marmots is clear from air photos and ground-truthing. Clasts of up to 30cm across can be undermined and somehow ejected at the entrance. With burrows often more than 1 to 2m deep, up to 50cm wide, and prone to backfilling, inwash and roof collapse, the Marmot galleries are a significant influence on many placers, particularly slope-derived solifluction deposits. The bioturbation presumably facilitates the downward migration of gold content within the placer, as well as ensuring the debris is kept loose enough to facilitate mass-creep downslope towards the valley floor. The chaotic nature of Marmot bioturbation renders old galleries indistinct in a solifluction placer, and this merits further study.

Polygonal Patterned Ground:

Remote sensing revealed polygonal 'patterned ground' which until then had escaped our attention. Formed by ice-wedge phenomena and associated expansion-contraction of the solifluction placers, in summer many are still active with open cracks up to 1cm wide at least 1.5 metres deep. Although discontinous, the polygons are each up to several metres across and affect about 10% of the surface extent of the placers. Clearly, when open, these may have had a major impact in allowing the solifluction deposit to trap gold passing above it from seasonal meltwaters, mudflows or floods. Furthermore, as internal conduits for groundwater and thixotrophic muds, the polygons may have had a major redistribution effect upon the fine gold content of the solifluction deposit. EMI investigated the extent to which pits dug in patterned ground are depleted or enriched in placer gold content, but no clear conclusion was reached.

The Sergelen Triangles

Remote sensing shows the dominant feature of otherwise unremarkable linear valleys to be distinctly darker triangular areas of vegetation, with sharp boundaries, the apex invariably pointing up-valley and with a 'side' of the triangle cutting across the valley approximately at right angles. More than 160 triangles are apparent with remote sensing, and are the dominant arial photography feature of a cumulative length of valley floors in excess of 50 km, and may have helped to trap placer gold The triangles seem to be related to damper soils.

EMI considered several competing explanations:

a) neotectonic origin, due to recent micro-faulting producing miniature steps across the valleys, causing impedence of drainage and triangles of lusher vegetation;
b) archeological origin, with small earth dams ponding back the water for livestock purposes and all the shallow ponds being now overwhelmed by lusher vegetation;
c) palaeo-forest origin, if fallen burnt timber criss-crossed the valley floors then a sequence of dammed areas would result now left as relict lush vegetation;
d) Artifacts of forest fires at the time the vertical air photographs were taken.

At present the ‘preferred origin’ is neotectonic. More investigation is required.

Contrast with the Zaamar Goldfield

The Sergelen Goldfield is heavily dominated by solifluction placers – as yet no alluvial placers have been recognized. In constrast the Zaamar Goldfield is dominated by alluvial placers of fluivial type. These fluvial placers are excellently exposed in placer mines on the Toson Terrace at Zaamar, such as in the Toson Mine of Java Goldfields Corporation.

However the Zaamar Goldfield also includes solifluction placers, such as at the Ikh Alt Mine of Ikh Alt Zaamar Ltd. In many parts of the Zaamaer Goldfield, the two types of placer occur superimposed and interdigitate. More field investigation is merited.

Fig.3: *Cross-bedded well-rounded well-sorted fluvial placer exposed in the Toson Mine of Java Gold Corporation (JVAG on CDN), Toson Terrace, Zaamar Goldfield.*

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References

Batbayar, Minjin, Baasandorj Altanzul, Robin Grayson, Baatar Tumenbayar, Tseveen-Ochir Altantsetseg, Iain Barclay, Bat-Otgon Bat-Ochir & Gerrit Bazuin (1999) Solifluction placers of the Sergelen Goldfield, Mongolia. *Mongolian Geoscientist, Bulletin of the Geological Association of Mongolia, volume 14, p.116-119. (in English)*

Beaudoin, Gary (2000) Gold Test on the Toson Terrace Placer, Zaamar Goldfield of Mongolia. *World Placer Journal, volume 1, p.1-9. (in English)*

Dallas, William (1999) An Assessment of Environmental Impact Issues and Issues Relating to Gold Mining in the Zaamar Region, Mongolia: Executive Summary. *World Bank. Washington DC. 13 pp. (in English)*

Farrington, John (2000) Environmental problems of placer gold mining in the Zaamar Goldfield, Mongolia. *World Placer Journal, volume1, p.107-128. (in English)*

Grayson, Robin (2000) The failure of Java Gold Corporation in placer gold mining in Mongolia. *World Placer Journal, volume 1, p.10-30. (in English)*

Tumenbayar, Baatar, Minjiin Batbayar & Robin Grayson (2000) Tantalite-cassiterite-ilmenite-monzanite-gold placer in Mongolia (Ta, Nb, Sn, Li, REE, Au). *World Placer Journal, volume 1, p.160-174. (in English)*

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