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MICROTEXTURES ON QUARTZ AND GOLD GRAINS TRANSPORTED BY GLACIERS

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ABSTRACT: Quartz and gold grains transported by mountain glaciers carry a range of microtextures (fractures and abrasion features) that are dependent mainly on ice thickness and distance of transport. Expanded mountain ice, forming extensive to thin valley glaciers with thicknesses of 500 m ± 200m, produces a range of fractures and abrasion features on quartz clasts as well as pounding, thinning and flattening of gold. On quartz grains these microtextures include conchoidal and subparallel linear fractures covering 10 - 40% of grain surfaces, minor crater and v-shaped percussion cracks, and abrasion features. Deep furrows and crescentic gouges often observed on quartz grains emplaced by continental glaciers with thicknesses of >800m, are conspicuously absent on quartz grains deposited by thin cirque glaciers (<200 m). Upturned plates on quartz, often considered to represent maximum cryostatic pressure, are also absent on quartz grains in mountain tills. Grain edge fractures and abrasion become relatively common on grains transported longer distances (50 km) in thicker valley glaciers. Quartz grains with complex weathering histories often show two or more periods of glacial crushing separated by different degrees of quartz dissolution.

Microtextures observed on quartz and gold sand and silt particles from the Bolivian Andes have been used to reconstruct glacial history and they are important in studying alluvial or glacial placer deposits. In many mountain areas it is important to know the limits of glaciations as well as the extent and depth of outwash deposits that extend to lower elevations. Microtextures on quartz and gold grains, as seen with the SEM, help to reconstruct the history of glacial and interglacial events that have shaped the land mass.

RESUME: Les grains de quartz et d'or transportés par les glaciers de montagne présentent une série de microtextures (fractures et marques d'abrasion) qui dépendent principalement de l'épaisseur de la glace et de la distance du transport. La glace étalée, formant des glaciers de vallée étendus ou minces avec des épaisseurs de 500 m ± 200 m, produit une série de fractures et marques d'abrasion sur les fragments de quartz, de même que le broyage, l'amincissement et l'aplatissement de l'or. Sur les grains de quartz ces microtextures comprennent des fractures linéaires conchoidales et subparallèles couvrant 10-40% de la surface de grains, des fentes de percussion en forme de petites cratères et en forme de V, et des marques d'abrasion. Des stries profondes et des gouges en forme de croissant souvent observées sur les grains de quartz transportés par les glaciers continentaux dont les epaisseurs dépassent 800 m, sont remarquablement absentes sur les grains de quartz deposés par de minces glaciers de cirque (<200 m). Les plaques retournées sur le quartz souvent considérées comme indicatrices de la pression cryostatique maximum, sont également absentes sur les grains de quartz dans les tills de montagne. Les fractures des bords de grain et l'abrasion deviennent relativement communes sur les grains transportés sur des distances plus longues (50 km) dans d'épais glaciers de vallée. Les grains de quartz ayant des histoires complexes

d'altération présentent souvent 2 ou plusieurs périodes d'écrasement glaciaire séparées par différents degrés de dissolution de quartz.

Les microtextures observées sur les grains de quartz et d'or de la taille du sable et des particules d'argile des Andes de Bolivie ont été utilisées pour reconstruire l'histoire glaciaire et elles sont importantes dans l'étude des dépôts de placers alluviaux ou glaciaires. Dans de nombreuses zones de montagne il est important de connaître les limites de la glaciation de même que l'étendue de la profondeur des dépôts d'epandage fluvio-glaciaire qui s'étendent à des altitudes plus basses. Les microtextures sur les grains de quartz et d'or, comme le montre le MEB, aident à reconstruire l'histoire des événements glaciaires et interglaciaires qui ont modelé le terrain.

INTRODUCTION

Microtextures on quartz sand grains have been used as evidence for transportation and emplacement by glaciers (Krinsley and Donahue, 1968; Krinsley and Doornkamp, 1973; Margolis and Krinsley, 1974; Whalley and Krinsley, 1974). More recent studies have shown that the range and intensity of microtextures can be used to determine ice thickness (Mahaney, 1991a; Mahaney et al., 1988). Attempts at paleoenvironmental reconstruction have also been made (Krinsley and Doornkamp, 1973; Bull, 1981; Mahaney, 1991b). Almost all microtexture studies have concentrated on quartz, zircon, and/or rutile minerals (Tejan-Kella et al., 1991) with some studies including plagioclase grain (Mahaney, 1991b). All of these minerals have hard, resistant surfaces that are subject to brittle fracturing, processes which give rise to conchoidal and linear fractures, arc-shaped steps and crescentic gouges of various kinds.

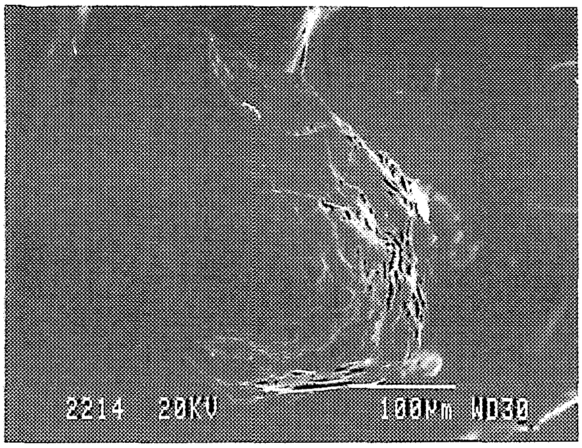
The use of microtextures on gold particles for paleoenvironmental reconstruction has been attempted by numerous investigators including Hérail et al. (1988, 1990). Gold which is a highly ductile and malleable metal is subject to considerable corrosion as well as thinnning, pounding and folding processes which assist in reconstructing the origin of gold placers.

In theory, the analysis of gold with quartz in the same deposits should provide a considerable amount of paleoenvironmental information regarding the sedimentary processes responsible for the evolution of gold placer deposits. The purpose of this short report is to present the results of a preliminary test carried out on gold and quartz grains from the Peruvian Altiplano.

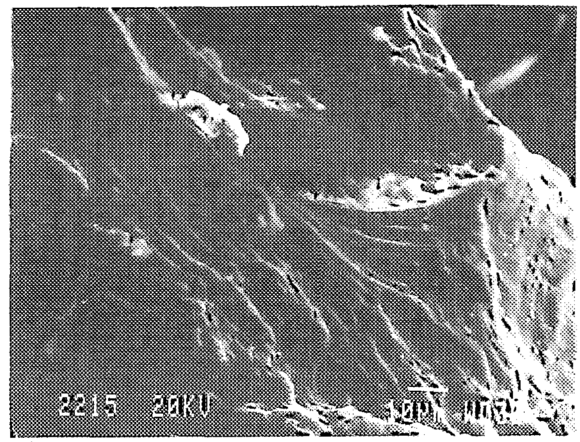
Fig. 1 A, Gold pounded over quartz with some adhering particles. Samples from Y till group, Lake Suches, Peruvian Andes; B, Enlargement of quartz in A showing weathered conchoidal and minor subparallel linear fractures. Age is pre-Würm.

Fig. 2 A, Quartz "island" surrounded by flattened gold in same sample as Fig. 1. Some Al coatings probably reflect preglacial weathering; B, old weathered fractures on quartz (right) next to gold with slight corrosion features.

Fig. 3 A, Rounded quartz particle in Y Group sample showing minor lunate craters (arrow-l) and v-shaped percussion cracks (arrow - p); B, Lake Suches grain C showing fold pounded over quartz but not excessively thinned. Note cracks between gold sheets of the Antaquilla Glaciation (early Würm).



1A



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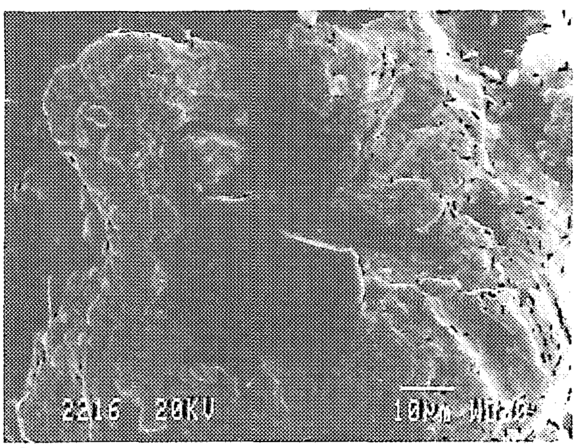
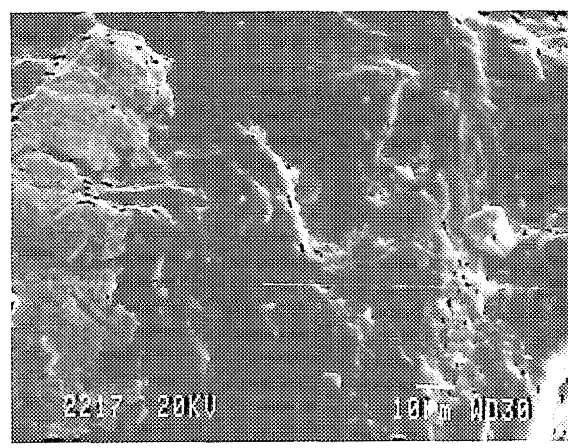


2A



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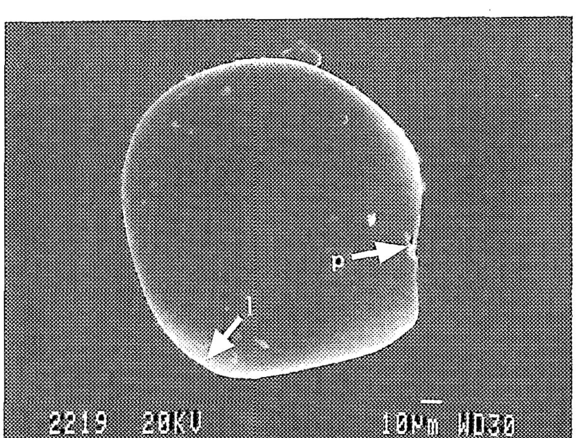
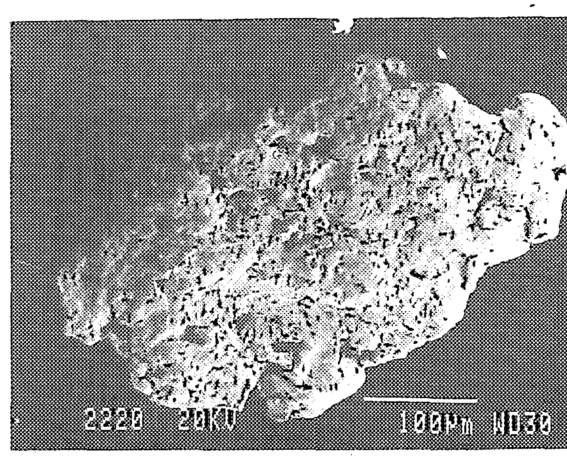
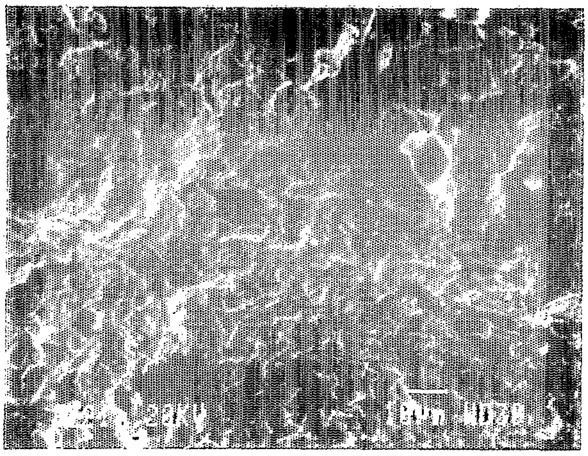


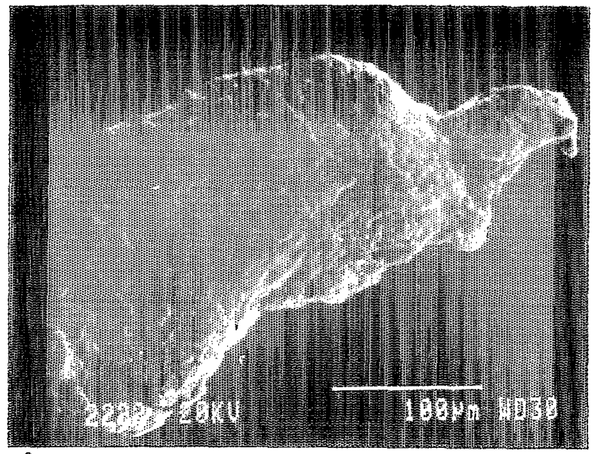
3A



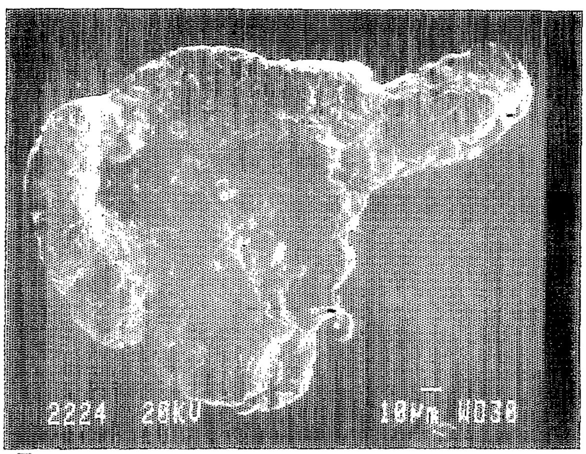
3B



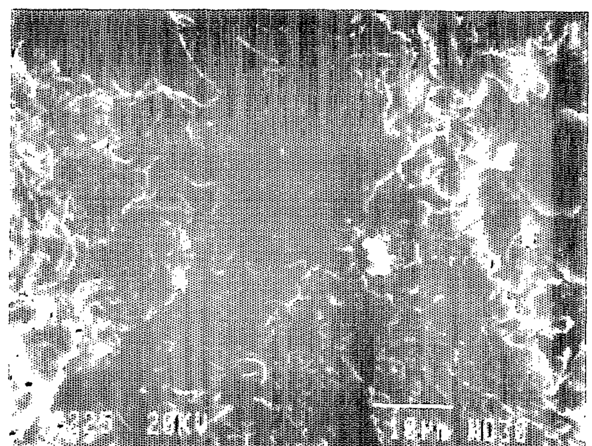
4A



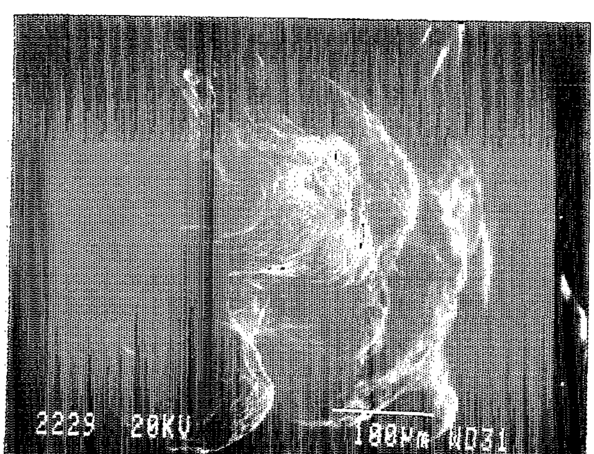
4B



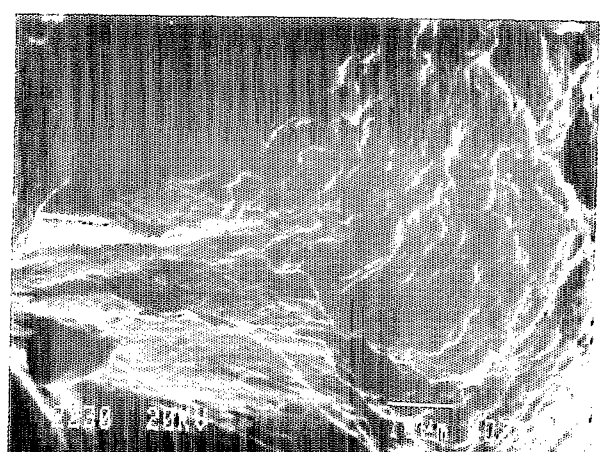
5A



5B



6A



6B

METHODS

The samples were recovered from bulk samples collected from gold placers and glacial deposits in Peru. The samples were dry sieved to separate the pebble from the <2 mm material (Day, 1965). The <2 mm fraction was panned and the heavy concentrate air dried. Subsamples of the dried material were prepared using a binocular microscope, coated with carbon and analysed with a JEOL 840 scanning electron microscope and PGT energy dispersive X-ray microanalyzer.

RESULTS

A sequence of gold and quartz-bearing tills from Lake Suches, Peru, was analyzed by SEM to determine if microtexture data would provide new information on paleoenvironmental reconstruction. For the purpose of this paper I concentrated on samples containing both quartz and gold and on representative subsamples from each of three age-groups of tills (Hérail, 1991): Ajanani (pre-Würm), Antaquilla I (early Würm) and Antaquilla II (late Würm). Because these tills are from moraines with increasing transport distance from the local ice centers, each younger glaciation represents a progressively thinner ice sheet (ice cap during the pre-Antaquilla to expanded mountain ice during the Antaquilla to valley glaciers during the Ajanani).

In the pre-Antaquilla sample (Y group) gold was usually found pounded over quartz (figs. 1A and 1B). Quartz grains were usually well fractured and most were well weathered. The gold particles showed relatively little corrosion indicating the quartz grains were preweathered whereas the gold was pounded on during transport. In the same sample, quartz "islands" are surrounded by flattened and pounded gold folded over the quartz surface. Aluminium coatings on these quartz islands suggest preweathering (fig. 2A). Again, because the gold shows only minor corrosion, it is likely the quartz grain particles were crushed and weathered prior to gold being pounded around the quartz grain (fig. 2B).

Some quartz grains are rounded showing minor impact craters and v-shaped percussion cracks (fig. 3A). Very few grains in this sample suite showed v-shaped percussion scars, but because the sample suite is so small (n=5) it is difficult to draw any generalizations. Certainly tills in other alpine areas are known to contain a wealth of percussion cracks that are believed to result from meltwater transportation (Mahaney, 1991a; Mahaney et al. 1988, 1989).

Fig. 4 A, Multiple sheeting effect with suture lines between sheets. Minor corrosion or dissolution effects on the surface; B, "El Condor" grain of gold from Antaquilla till showing multiple sheeting effect.

Fig. 5 A, Overview of grain showing quartz "islands" and some cavities with Fe coats. Gold sheets pounded and thinned out over ca. 80% of the particle surface; B, enlargement of flattened gold with suture lines in lower right hand side of A above.

Fig. 6 A, Overview of grain from youngest till in Peruvian Andes. Sample is from sluiced gravel and consists of primary gold showing no pounding, flattening or thinning characteristics - A, massive equant grain; B, Enlargement of grain in A showing primary mineral growths. To lower right are spreading features with minor corrosion.

Quartz and gold grains from the Antaquilla till (early Würm) showed pounded but not thinned gold coats over quartz (fig. 3B). Often a multiple sheeting effect with or without suture lines is present on the samples studied (figs. 4A and 4B). As with the older pre-Antaquilla tills some quartz grains have "islands" of well-fractured surfaces that were preweathered and contain iron coatings (fig. 5A). Gold sheets pounded and partially thinned out are common. Enlargements (fig. 5B) of these flattened gold particles with suture lines show a considerable amount of ductile deformation presumably produced by glacial transportation.

Gold grains in the youngest till showed equant forms with little or no pounding, thinning, and flattening (figs. 6A and B).

DISCUSSION

Microtextures commonly observed on quartz and gold grains in glacial deposits are shown on Table 1. Some of the microtextures such as grooves, crescentic gouges, and arc-shaped steps were not encountered in the samples studied presumably because all were from thick to thin valley glaciers. Shallow and deep grooves, crescentic gouges and arc-shaped steps, are all known primarily from quartz sands in thick continental tills (Mahaney, 1990a, 1991a).

Table 1: Microtextures common to both gold and quartz grains in glacial deposits

MICROTEXTURES	GOLD	QUARTZ
Cracking	X	X
Roundness/Angularity	X	X
Thinning	X	
Folding	X	
Pinching	X	
Solution etching	X	X
Patina impact craters	X	X
Percussion cracks	X	X
Corrosion pits	X	X
Impact craters	X	X
Linear fractures		X
Conchoidal fractures	?	X
Grooves	X	X
Crescentic gouges		X
Arc-shaped steps		X
Preweathering	X	X
Weathered crushing features		X
Adhering particles	X	X

Almost all fractures and impact craters are predominantly found on quartz but not on gold. Adhering particles, which are often considered to reflect the degree of glacial grinding (Smalley, 1966), seem to have the same degree of cover on both gold and quartz grains. However, the mineralogy of adhering particles on both gold and quartz is predominantly quartz, plagioclase feldspar or amphibole. Most probably if any gold is left as an adhering particle it is quickly pounded and flattened into the gold surface by pressure of the ice.

If there is any validity to the hypothesis proposed by Mahaney et al. (1988, 1989) that relates the range and intensity of microtextures on quartz to ice thickness, it should be possible to continue with the analysis of quartz and gold grains from Altiplano tills to either prove or disprove the theory. Certainly the degree of pounding, thinning and flattening of gold is compatible with expanded mountain ice. As well, the prevalence of preweathered quartz grains showing evidence of fracturing -> weathering -> transport parallels similiar sequences observed in tills from other localities in North America (Mahaney 1990a), Africa (Mahaney, 1990b, 1991b, 1991c) and Antarctica (Mahaney, 1991a).

CONCLUSIONS

There are number of conclusions that can be made from this study. From the limited data set it is possible that a large number of quartz grains were fractured during a previous glaciation (Antaquilla or - pre-Antaquilla), weathered during a subsequent interglaciation and then transported during a subsequent glaciation. The absence of fresh fracturing on these grains indicates either that transport distances were short or that the ice was thin. In some cases it might be that gold protected the quartz surface from fracturing or that it masks conchoidal and/or subparallel fractures.

The preliminary results discussed here suggest that it is worth expanding the data base to include thinner alpine tills (from cirques where ice thicknesses were less than 200 m) and thicker expanded mountain ice (ca. 500 m ice thickness) to continental glaciers where ice thicknesses are commonly + 1000 m. It may well prove possible to use quartz and gold from the same subsamples to infer glacial transport and to assist in paleoenvironmental reconstruction.

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