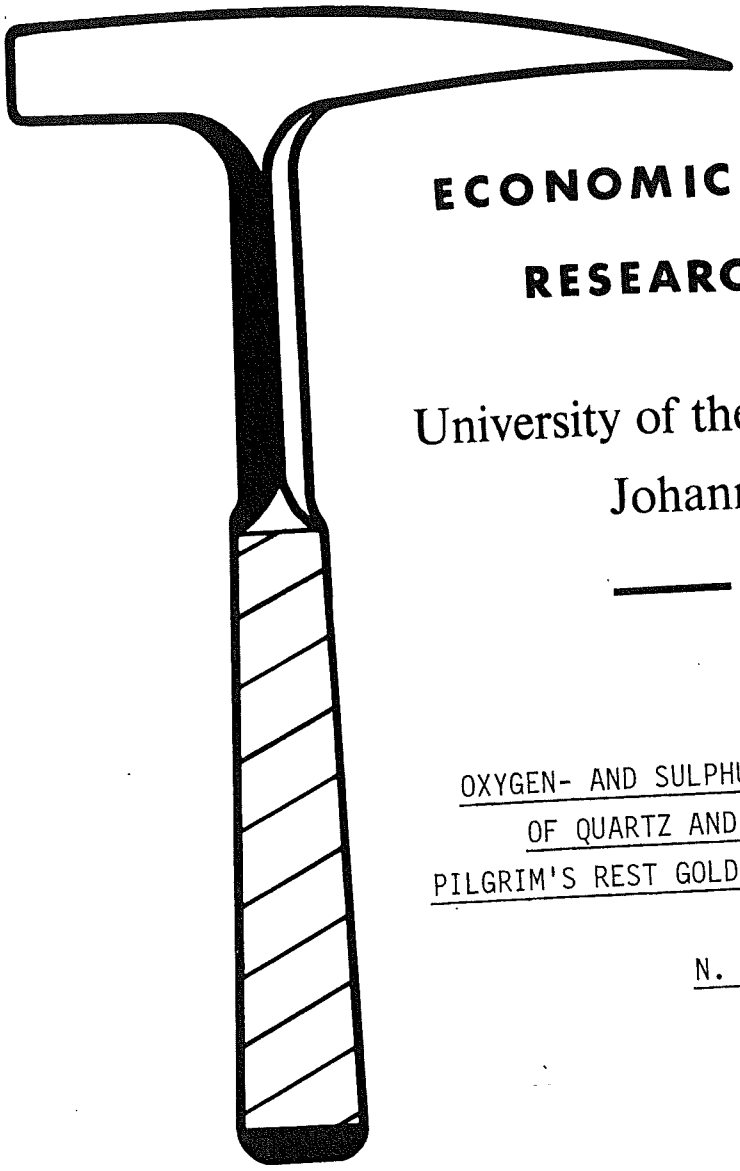

ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
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OXYGEN- AND SULPHUR-ISOTOPE PROPERTIES OF QUARTZ AND PYRITE FROM THE PILGRIM'S REST GOLDFIELD, EASTERN TRANSVAAL

N. TYLER

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UNIVERSITY OF THE WITWATERSRAND
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by

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CONTENTS

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OXYGEN- AND SULPHUR-ISOTOPE PROPERTIES OF QUARTZ AND PYRITE FROM THE PILGRIM'S REST GOLDFIELD, EASTERN TRANSVAAL

To supplement field and fluid-inclusion studies of quartz-pyrite-gold veins at Pilgrim's Rest, six pyrite samples and nine quartz samples were analyzed to determine the sulphur- and oxygen-isotope properties of the ore-veins. Sulphur-isotope analysis was undertaken by the Coastal Studies Laboratory, a commercial analytical laboratory, in Austin, Texas; oxygen-isotope analysis was kindly provided by Professor Lynton Land, of the Department of Geological Sciences, the University of Texas at Austin.

OXYGEN-ISOTOPES

Nine samples of vein-quartz were obtained from two reefs in the basement granite and at different stratigraphic levels in the overlying Transvaal Supergroup (Fig. 1). Four samples were from strata-bound, "bedded" ore-bodies in the Malmani Dolomite, two from the Peppersteak Reef in the Pretoria Group (also a strata-bound vein), and two samples from the vertical feeder-reefs in the basement granite. A single sample was obtained from the Trixie Leader, a stockwork developed in the Wolkberg Group, below the Black Reef Quartzite.

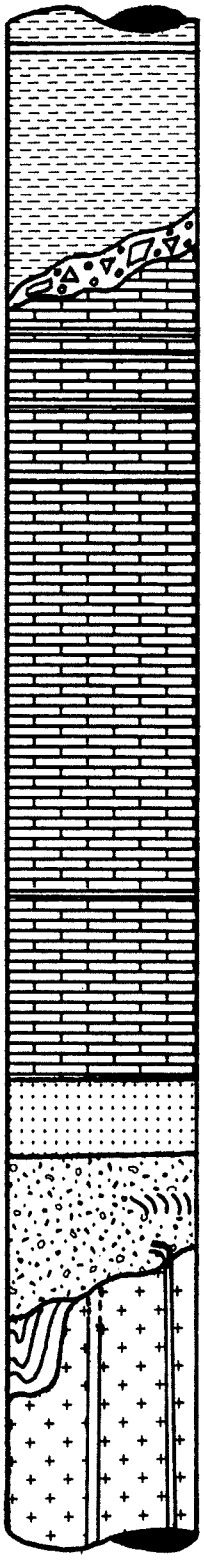
All of the samples fall in the range $\Delta^{18}O$ +12,1 to +19,5°/$_{oo}$ (Fig. 1). The strata-bound bodies in the Malmani Dolomite (Vaalhoek, Portuguese, Beta, and Theta reefs) display $\Delta^{18}O$ values tightly clustered between 17 and 18°/$_{oo}$. The vertical feeder-bodies are characterized by slightly-lower, isotopic compositions (14,1 to 15,2°/$_{oo}$). Strata-bound ore-bodies in shales of the Pretoria Group exhibit the lowest, isotopic compositions (12,1 to 14,4°/$_{oo}$). In contrast, $\Delta^{18}O$ values are highest in the Trixie Leader.

Although the samples display a relatively narrow range of oxygen-isotope compositions, there is a systematic variation in the isotopic make-up of the quartz. Several possible mechanisms may account for the variability :

1. The compositions might have been affected by host-rock lithology. The quartz is isotopically heaviest in the dolomite, intermediate in the granite, and lightest in shale. This, however, would imply low fluid-to-rock ratios in the mineralized zone, atypical of Archean lode-gold deposits in general (Colvine and others, 1984), but would explain the absence of pervasive, wall-rock alteration adjacent to the veins.

2. The fluids might have evolved with height in the stratigraphic column. If it is accepted that the vertical veins in the granites were the feeders for the strata-bound bodies, which is supported by field relations and fluid-inclusion data (Ash and Tyler, in press), then the mineralizing brines matured from isotopically-light (in the granite) to isotopically-heavy compositions (in the dolomite). Higher in the succession, the isotopic compositions once again shifted to the lighter end of the spectrum. One possible cause for the latter shift might have been

Stratigraphic column	Sample localities	$\Delta^{18}O^{\circ}$ °/oo	$\Delta^{34}S^{+}$ °/oo
Pretoria Group	Peppersteak reef	12,1 14,4	
Bevetts Conglom.			
	Theta reef	17,5	+0,5 +3,7
	Beta reef	17,2	+2,5
	Portuguese reef	17,3	+2,4
Malmani Dolomite			
	Vaalhoek reef	18,0	+4,0
Black Reef			
Wolkberg Group	Trixie leader	19,5	+2,5
	Gregory reef	15,2	
Basement Complex	Rietfontein reef	14,1	



Analysts: ° Professor L. Land, The University of Texas
+ Coastal Studies Laboratory, Austin, Texas

Figure 1 : Simplified stratigraphic column, locations of sample-sites, and isotopic characteristics of Pilgrim's Rest vein-deposits.

mixing with formation-waters retained in the Pretoria shales or with isotopically-light groundwater.

3. Mineralization at different stratigraphic levels in the column might be unrelated. This is considered unlikely, as the composition of fluid-inclusions from veins in the dolomite and in the granite are similar (Ash and Tyler, in press) and support a single source, at least for this system.

SULPHUR-ISOTOPES

The sulphur-isotopic composition of pyrite from four strata-bound veins and from a single sample of the Trixie Leader all fall in the narrow range of $\Delta^{34}S$ +0,5 to 4,0°/$_{oo}$. Unlike oxygen-isotopes, where the Trixie Leader sample was isotopically heaviest, the Trixie Leader falls within the range displayed by the strata-bound ore-bodies (Fig. 1).

DISCUSSION

When considered individually, the sulphur-isotope data from Pilgrim's Rest are non-diagnostic. The range of values for the Pilgrim's Rest samples falls within fields displayed by $\Delta^{34}S$ in igneous rocks, volcanics, evaporites, sedimentary sulphides, hydrocarbons, and even rain and snow (Kaplan, 1983). However, many of these possible options are readily dismissed in the context of the constraints imposed by the geology of Pilgrim's Rest. Oxygen-isotope data are more diagnostic. The Pilgrim's Rest samples clearly fall beyond the limits of meteoric water and evolved, meteoric and formation-water (Fig. 2). Further, Pilgrim's Rest vein-quartz is isotopically unlike Tertiary replacement-bodies in the Great Basin, USA. There is a far better correlation with magmatic and metamorphic water (Fig. 2). Returning to sulphur, within the context of Transvaal geology and the $\Delta^{18}O$ data, meteoric water and hydrocarbons can be eliminated from serious contention. No extensive evaporite and/or sedimentary sulphur accumulations, large enough to serve as a source for the sulphur, have been described from the area, leading to the conclusion that the sulphur- and quartz-bearing brines were derived from a magmatic source and/or from metamorphic dehydration and degassing of the underlying basement lithologies.

The Pilgrim's Rest vein-deposits display many similarities with Archean lode-gold deposits. Fluid-inclusion characteristics are compatible (Ash and Tyler, in press). The isotopic composition of quartz and pyrite is also similar (Fig. 2), although quartz from Pilgrim's Rest is slightly heavier, isotopically, than quartz in Archean lode-gold deposits. The genesis of Archean lode-gold deposits has been the topic of much debate. Recently, the post-kinematic or syn-metamorphic school of thought, fortified by isotopic data, has been accepted over the previously-widely-held belief of a syngenetic origin. Colvine and others (1984) concluded that the mineralizing fluids in lode-gold systems were derived from a

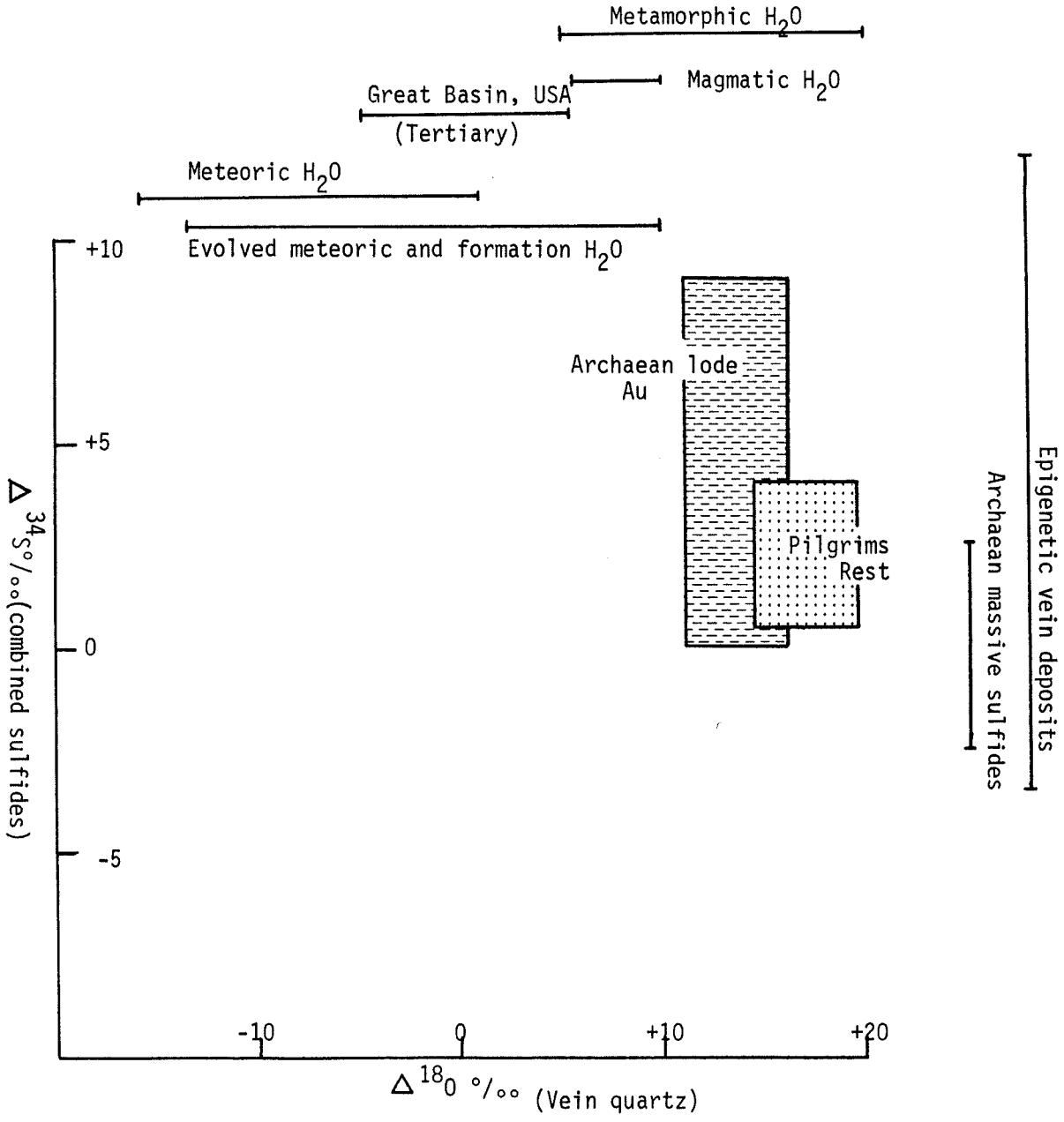


Figure 2 : *Isotopic composition of quartz and pyrite from Pilgrim's Rest, compared with compositions from other environments. Modified from Colvine and others (1984).*

magmatic or metamorphic source. They further concluded that the fluids were dominated by reduced species.

All available evidence points to a similar origin for the Pilgrim's Rest gold-bearing veins. It is concluded that the mineralizing fluids were obtained from either a magmatic source (possibly coupled with late-Transvaal volcanism or Bushveld intrusion) or from metamorphic devolatilization of the underlying rock-column.

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ERRATA

Information Circular No. 181

Information Circular No. 181 originated as an interim progress report supplied to EGRU by the author. It was not intended for general publication. Requisite manipulation of the unprocessed, isotope-data leads to somewhat different conclusions than those presented in Information Circular No. 181. These conclusions were published in Information Circular No. 179.

Page 3, Discussion, lines 7, 8, 9: This statement refers to the isotope-composition of quartz gangue. However, the calculated, isotopic composition of the mineralizing fluids, determined from $\delta^{18}O$ quartz, using Friedman's and O'Neil's (1977) modified oxygen-isotope separation-factors of Clayton et al. (1972), shows that, while the mineralizing fluids were probably of metamorphic or igneous origin, they interacted with saline, evolved, formation-waters in the sediments and, to a lesser extent, deeper in the stratigraphic column.

Page 3, Discussion, line 14: While thick evaporite-assemblages have not been found in the Chuniespoort Group, there is evidence that parts of the Chuniespoort depositional environment may have been sabkha-like. Remnant, evaporitic textures, such as salt-casts and chicken-wire structures, are present, particularly in the Transition-Zone of the Malmani Dolomite. Evaporites now dissolved, replaced by carbonate, or otherwise destroyed, or perhaps undetected in the subsurface, probably contributed to the salinity of the evolving formation-waters and, in turn, to the anomalously-high salinity of the fluid-inclusions in the quartz gangue. See Information Circular No. 179 for an expanded discussion of these concepts.

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