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Evidence for recycled Mesoarchean crust in the Ruttan arc succession, Rusty Lake belt, Trans-Hudson Orogen, Manitoba: U-Pb isotopic data[1]

D.E. Ames, O. Van Breemen, and J.S. Scoates

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Abstract: New U-Pb zircon data are reported for the Paleoproterozoic volcanic rocks in the Rusty Lake belt of the Trans-Hudson Orogen. A massive volcaniclastic sample from the Ruttan volcanic succession, host to the solitary, giant 89 Mt Ruttan Cu-Zn volcanogenic massive sulphide deposit, yielded zircons with an age of 3.0 Ga. The zircons are interpreted as xenocrysts derived from Mesoarchean crust or from meta-sedimentary rocks containing such zircons. These data raise new questions and contribute to a better understanding of the nature and evolution of the northeastern Trans-Hudson Orogen.

Résumé : La présente étude fait part de nouveaux âges définis par la méthode U-Pb sur zircon pour les roches volcaniques du Paléoprotérozoïque de la ceinture de Rusty Lake, dans l'orogène trans-hudsonien. Dans la succession de roches volcaniques de Ruttan qui renferme le gisement géant (89 Mt) et solitaire de Ruttan, un amas de sulfures massifs volcanogènes à minéralisation de Cu-Zn, un échantillon massif de roches volcanoclastiques a livré des zircons datant de 3,0 Ga. Ces zircons seraient des xénocristaux provenant d'une croûte mésoarchéenne ou dériveraient de roches métasédimentaires contenant de tels minéraux. Ces données soulèvent de nouvelles questions mais permettent de mieux comprendre la nature et l'évolution de la section nord-est de l'orogène trans-hudsonien.

[1] Contribution to EXTECH I

INTRODUCTION

The 89 Mt Ruttan deposit is the largest volcanogenic massive sulphide deposit hosted by greenstone belts of the Paleoproterozoic Trans-Hudson Orogen (Fig. 1). The isolation of this solitary, large volcanogenic massive sulphide deposit within the Rusty Lake belt of the Leaf Rapids–Rusty Lake domain was the focus of a detailed geological mapping project centred on the Ruttan host succession (Ames and Scoates, 1992; Ames, 1996; Ames and Taylor, 1996).

The ca. 1.88 Ga Rusty Lake volcanic belt was distinguished from the older Lynn Lake Belt on the basis of U-Pb dating of a single felsic sequence in the entire 75 by 35 km belt (Baldwin et al., 1987). The depositional age of the volcanic sequence that hosts the giant 89 Mt Ruttan Cu-Zn deposit was unknown. This paper presents the results of a U-Pb study of felsic volcanic rocks associated with the Ruttan deposit, and will discuss the implications of the results with respect to the tectonic setting of the Rusty Lake belt and evolution of the northern boundary of the juvenile Trans-Hudson Orogen (Corrigan et al., 2001).

SYNOPTIC GEOLOGICAL SETTING

The Rusty Lake belt forms part of the 'Reindeer zone' of the Paleoproterozoic Trans-Hudson Orogen, interpreted to have formed during oceanic convergence and collision of the Archean Hearne and Superior cratons (Fig. 1). The southern

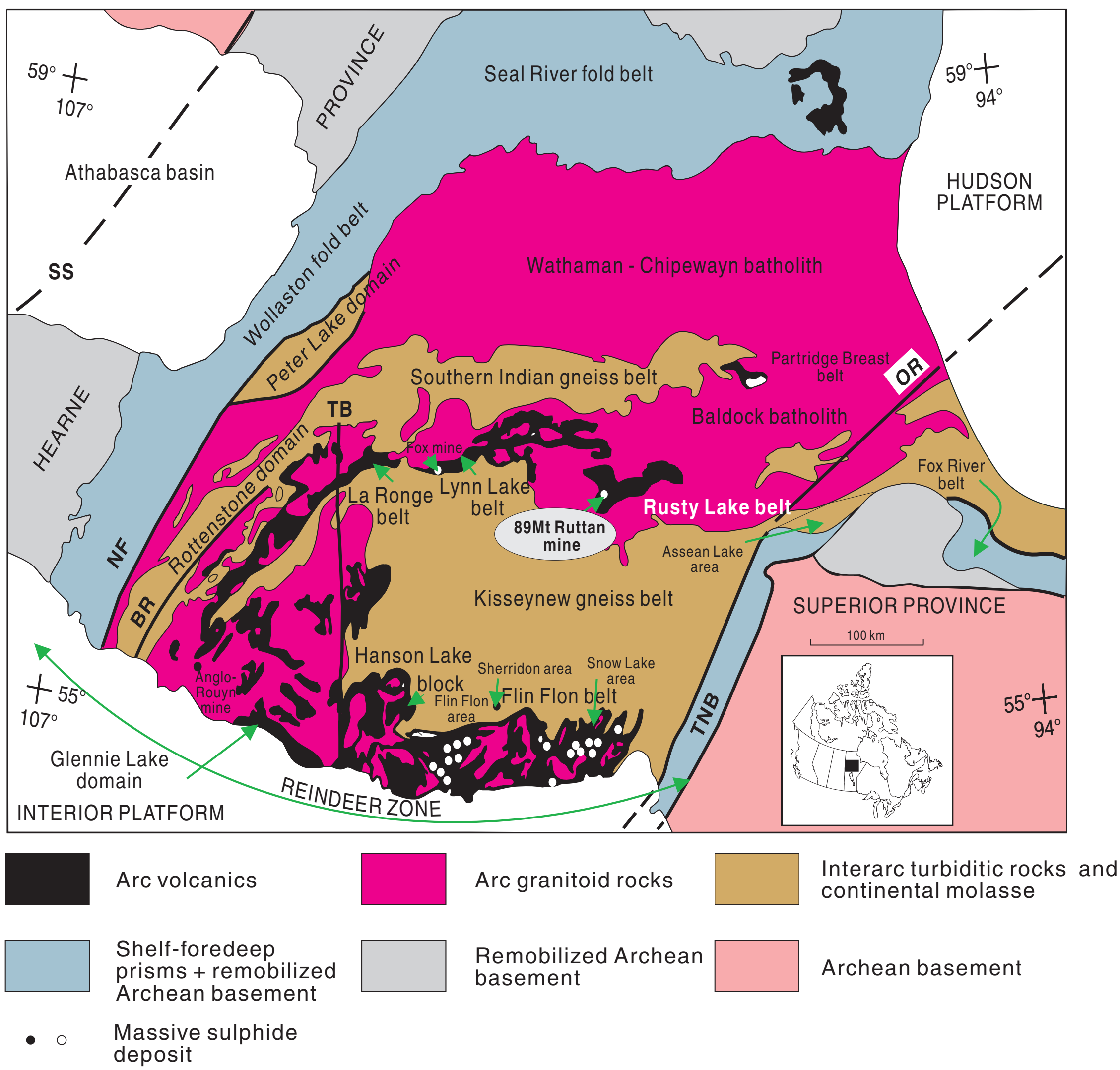

Figure 1. *Location and main geological divisions of the Trans-Hudson Orogen in northern Manitoba and Saskatchewan* (modified from *Hoffman, 1988 [with permission, from the Annual Review of Earth and Planetary Sciences, v. 16 ©1988 by Annual Reviews www.AnnualReviews.org]. BR, Birch Rapids shear zone; NF, Needle Falls shear zone; OR, Owl River shear zone; SS, Snowbird shear zone; TB, Tabbernor Fault; TNB, Thompson Nickel Belt*

half of the Rusty Lake belt is composed of mafic and felsic volcanic rocks with lesser metasedimentary rocks, whereas the northern half is dominantly metasedimentary with minor mafic volcanic and trace felsic volcanic rocks identified (Fig. 2). Previous mapping divided the Rusty Lake belt into four structural blocks: Ruttan, Karsakuwigamak, Northern, and Eastern (Fig. 2; Baldwin, 1988). Detailed mapping has been completed on the Karsakuwigamak (Baldwin, 1982, 1987, 1988) and Ruttan blocks (Ames and Scoates, 1992; Ames, 1996). Deposit-scale studies were completed on the Ruttan volcanogenic massive sulphide deposit by Ames and Taylor (1996), on the local geological setting (Ames et al., 1990; Ames, 1991, 1996), and on the Darrol Lake volcanogenic massive sulphide occurrence to the south (Barrie and Taylor, 2001). Recent lithogeochemical data, including rare-earth element results, exist only for the Ruttan mine area in the southwestern part of the belt (Ames, 1996; Ames and Taylor, 1996).

The Ruttan volcanic succession (Fig. 3) progresses upsection from ocean-floor basalt (Mill Pond formation) into a transitional arc to arc-tholeiite sequence (Vol formation) and arc-tholeiitic andesite (Trail formation; Ames, 1996). This is topped by approximately 300 m of siliciclastic rocks (Mine sequence), minor arc-tholeiitic basalt, and transitional tholeiitic–calc-alkalic rhyolite that hosts the Cu-Zn volcanogenic massive sulphide deposit (Ames, 1996; Ames and Taylor, 1996). The volcanogenic massive sulphide host succession is conformably overlain by turbidite with minor volcanic rocks of the Powder Magazine formation. The geochemistry and stratigraphic succession indicate that mineralization took place at the initiation of arc rifting (Ames, 1996; Ames and Taylor, 1996).

GEOCHRONOLOGY

Sampling for U-Pb geochronology included 1) the felsic volcanic suite of rocks in the giant Ruttan Cu-Zn mine, including the massive dacitic volcaniclastic rocks (‘Mine dacite’; sample 96-AV-08, fraction z6586), massive rhyolite (‘Mine rhyolite’; sample 96-AV-05, West anomaly orebody; sample 96-AV-09, 370 m level, Main mine), and upper felsic volcaniclastic rocks (sample 96-AV-11, 370 m level, Main mine; Fig. 4). The volcanic samples were collected to determine a depositional age for the deposit and potentially bracket the duration of ore deposition; however, preliminary attempts to obtain zircon from the Mine rhyolite were unsuccessful (sample 96-AV-09).

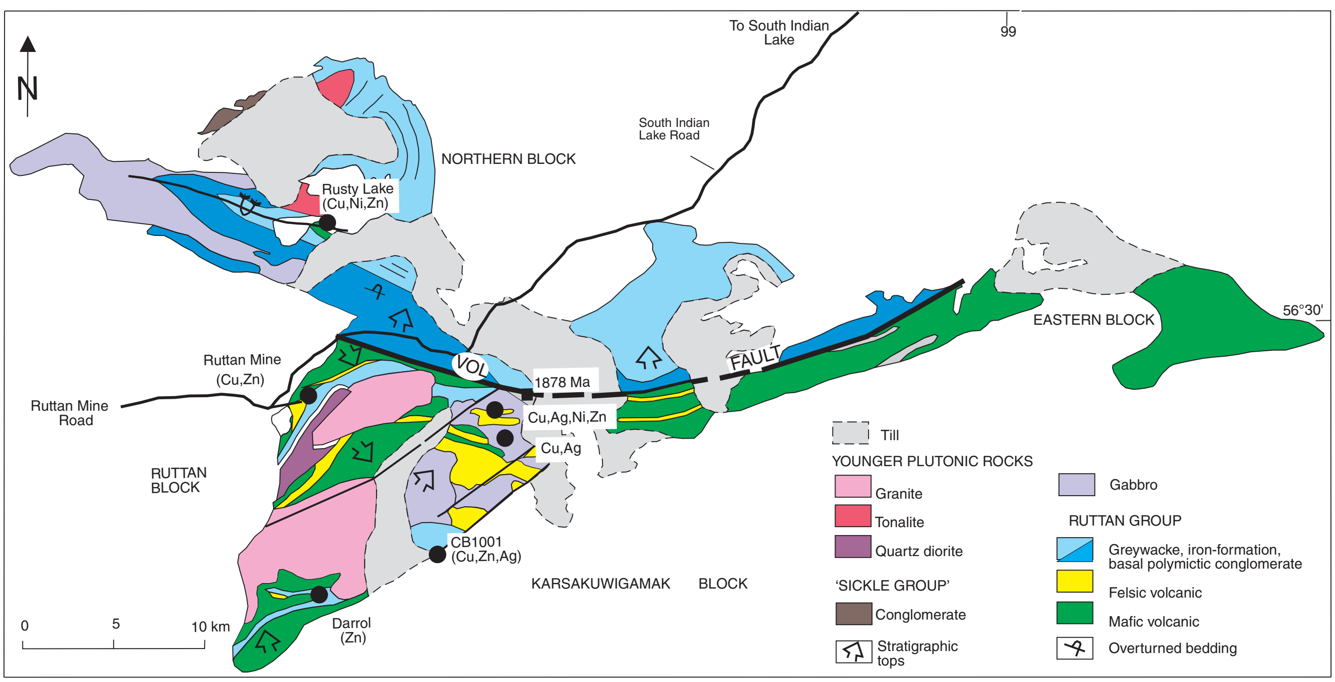

Figure 2. *General geology of the Rusty Lake belt, northern Manitoba.*

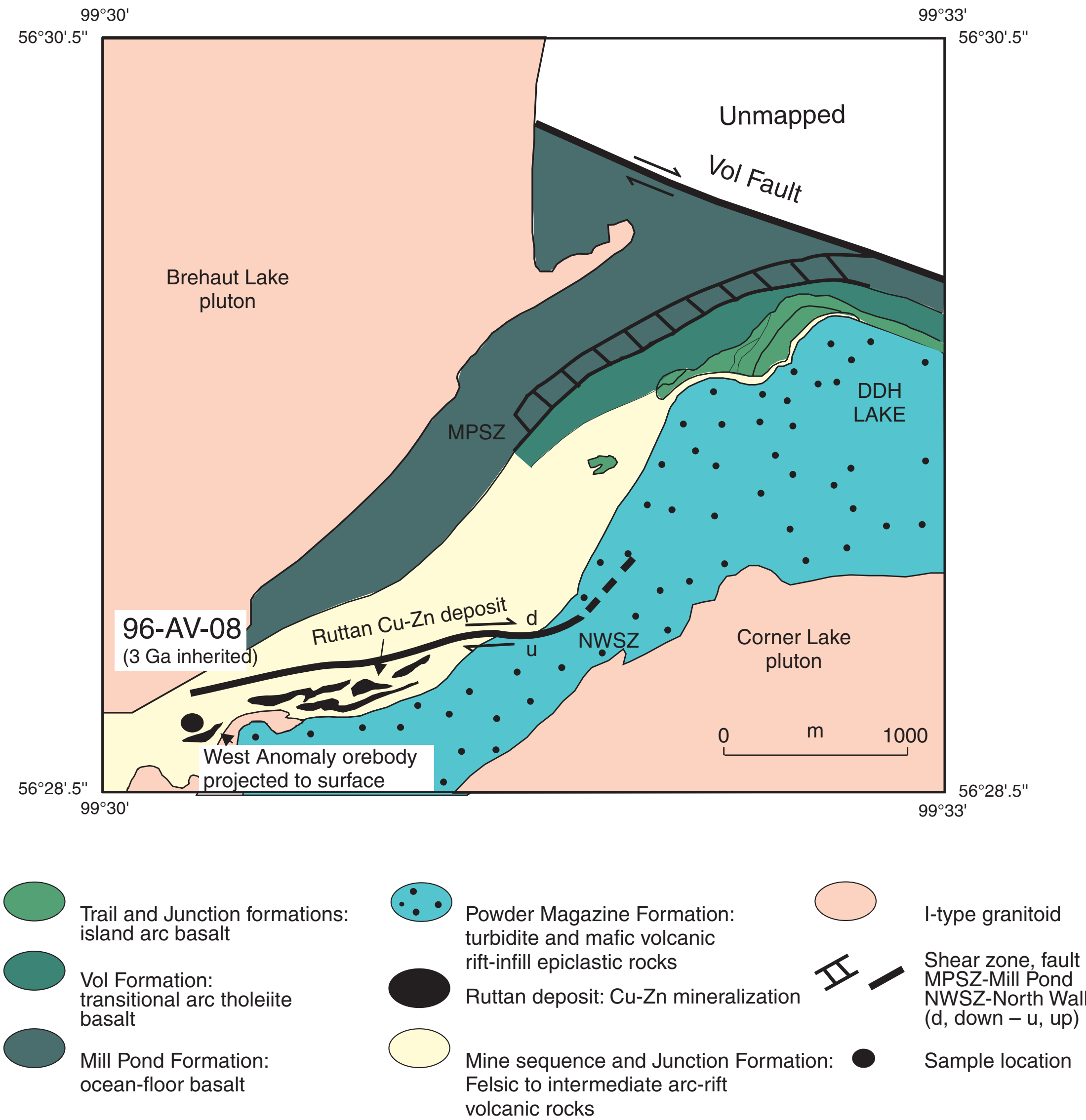

***Figure 3**. Simplified map summarizing the main tectonostratigraphy in the Ruttan mine area* (after *Ames, 1996).*

Analytical methods and results

A small population of zircon was recovered from the arc-tholeiitic dacitic volcanic rocks (sample 96-AV-08, fraction z6586; Fig. 4) upon which the rhyolite flow-lobe hyaloclastite and felsic volcaniclastic rocks that host the Cu-Zn mineralization were deposited. Zircon grains were typically prismatic, slightly rounded with no overgrowths, clear, and pale pink, with internal fractures and minor internal inclusions. Two subsets with three zircons in each fraction include fraction A with prismatic zircon and fraction B with prism fragments.

The two zircon fractions were lightly abraded (Krogh, 1982). Analytical techniques for measuring U-Pb isotopes in zircon and data-reduction methods used at the GSC Geochronology Laboratory are summarized by Parrish et al. (1987) and Roddick (1987). The isotopic data are presented in Table 1 and displayed on a concordia diagram in Figure 5. Age uncertainties are given at the 95% confidence level. Fraction A is concordant at 3004 ± 11 Ma, whereas fraction B is 3% discordant and yields a $^{207}Pb/^{206}Pb$ age of 3001 ± 2 Ma.

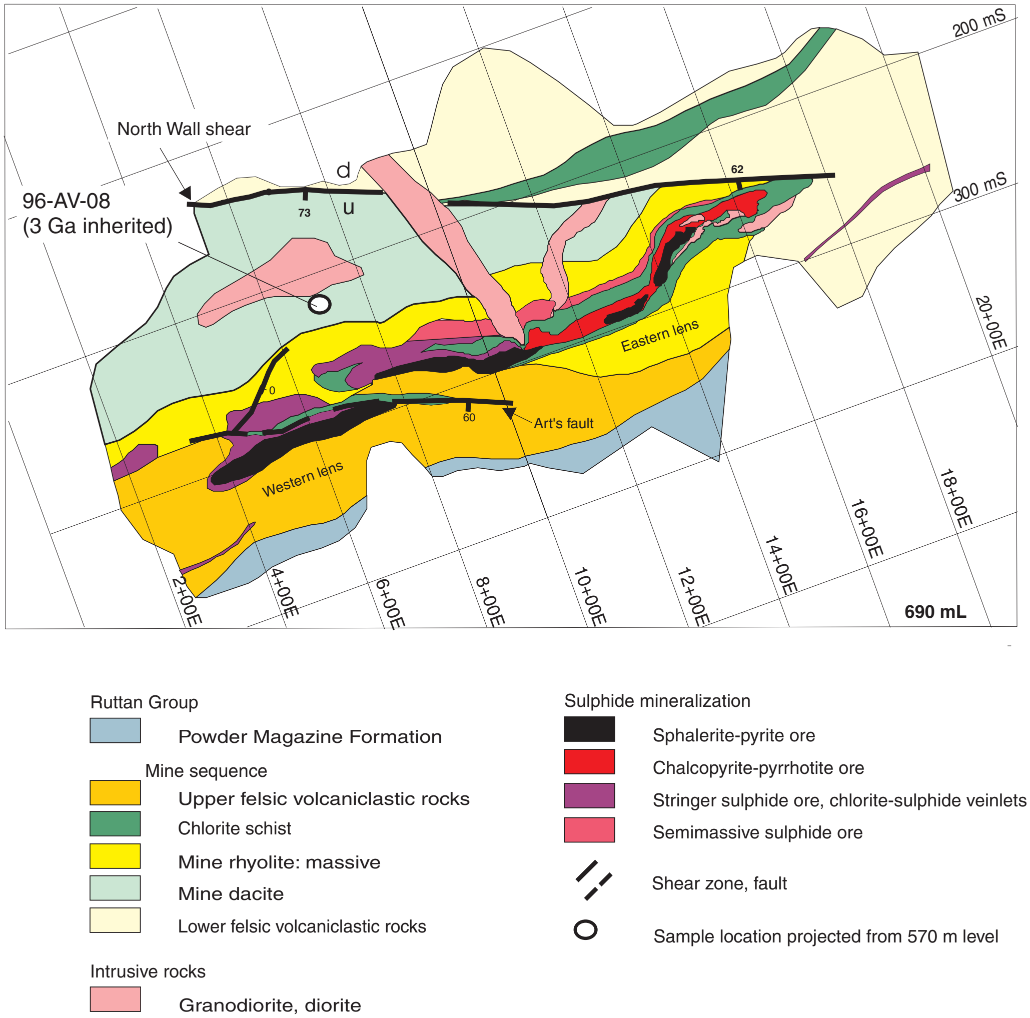

Figure 4. *Simplified geology of the West Anomaly orebody and Ruttan Cu-Zn mine, and location of geochronological sample* (modified from *Ames and Taylor, 1996*).

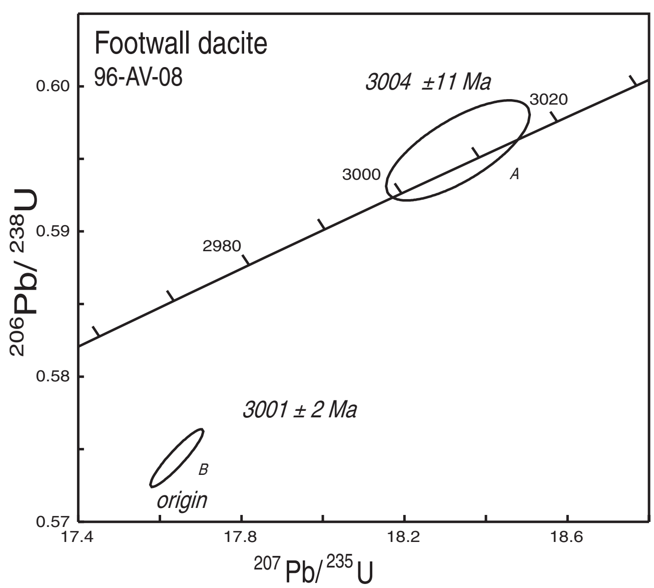

Figure 5.

U-Pb zircon concordia plot indicating $^{207}Pb/^{206}Pb$ model ages for data points, Rusty Lake belt. Data interpreted as 3 Ga xenocrysts.

Table 1. U-Pb analytical data for a dacitic volcaniclastic rock (z6586), Ruttan mine.

Fraction[1]	Weight[2] (μg)	U (ppm)	Pb[3] (ppm)	$^{206}Pb/^{204}Pb$[4]	Pb[5] (pg)	$^{208}Pb/^{206}Pb$[6]	$^{207}Pb/^{235}U$ (± 1σ)[6]	$^{206}Pb/^{238}U$ (± 1σ)[6]	$^{207}Pb/^{206}Pb$ (± 1σ)[6]	$^{207}Pb/^{206}Pb$ Age (± 1σ)[7]	Disc.[8]
Footwall dacite, Ruttan VMS deposit (sample 96-AV-08; fraction z6586):											
A (Z) 110 x 50	3	38	27	210	18	0.15	18.331 ± 0.48	0.5956 ± 0.29	0.22323 ± 0.34	3004 ± 11	-0.3
B (Z) 100 x 70	4	48	31	948	7	0.08	17.641± 0.18	0.5744 ± 0.17	0.22275 ± 0.07	3001 ± 2.2	3.1

1 Z, zircon; grain dimensions indicated are in μm; fractions are non-magnetic on a Frantz isodynamic magnetic separator at 1.8 A with a side slope of 5°
2 error on weight is ± 1 μg
3 radiogenic Pb
4 measured ratio corrected for spike and Pb fractionation of 0.09 ± 0.03 amu
5 total common Pb on analysis corrected for fractionation and spike
6 corrected for blank Pb and U, common Pb; errors quoted are 1σ (in percent[7])
7 age errors quoted are 2σ (in Ma)
8 discordance in per cent along a discordia to origin

DISCUSSION

The zircons are interpreted as inherited ages, and not as an Archean depositional age or laboratory contamination, because 1) the morphology of the zircon grains is inconsistent with a volcanic rock; and 2) felsic volcanism in the Rusty Lake belt was dated at 1.88 Ga (Baldwin et al., 1987). Neodymium isotopic data on flow and volcaniclastic rocks in the Ruttan succession are consistent with the U-Pb isotopic data in that they reveal evolved isotopic signatures at 1.8 Ga (D. Ames, unpub. data, 2002). It is inferred from this inherited zircon age that arc-rift volcanism tapped a source that included Mesoarchean crust or metasedimentary rocks containing such zircon.

Implications of U-Pb zircon data for tectonostratigraphic setting

Since the discovery of ancient (pre-3.5 Ga) crust along the northwestern boundary of the Superior craton (Bohm et al., 2000), the nature and location of the Trans-Hudon Orogen–Superior craton boundary has been questioned. The data from this study, located approximately 150 km west of the Assean Lake area (Fig. 1), reveal that Mesoarchean (3 Ga) crust was also involved throughout the development of the (ca. 1.88 Ga) Ruttan arc assemblage, presently situated between the Kisseynew domain and the Wathaman continental-arc batholith. The three Archean cratons with a potential role in the magmatism in the Trans-Hudson Orogen include, in likely order of significance to the Rusty Lake belt the 3.05 to >3.8 Ga Assean Lake area of the Superior craton (Bohm et al., 2000), the 3.2 to 2.4 Ga Sask craton (Ansdell et al., 1995; Ashton et al., 1999), and the Hearne craton (Loveridge et al., 1987). The precise origin of these 3.0 Ga zircons is unclear. The discovery of Mesoarchean crustal contamination in the Rusty Lake belt could be related to the inclusion of a slab of continental crust or sediment on the subducting plate, or to a rifted continental-margin setting for the formation of the Ruttan arc assemblage. These data suggest a role for Archean recycling in magmatism, particularly in the northern Trans-Hudson Orogen.

The presence of Neoarchean contamination and segments of old crust (Sask craton) in the internal zone of the Trans-Hudson Orogen are evident (Ansdell et al., 1995; Stern et al., 1995; Ashton et al., 1999), but these are not well documented regionally. In the Flin Flon belt to the south, juvenile Paleoproterozoic crustal evolution is complicated by the presence of Neoarchean inherited zircon (2.7 Ga) in the (ca. 1.9 Ga) Snow Lake oceanic-arc assemblage, plus 2.5 Ga tonalite slivers within crustal-scale fault systems transecting the greenstone belt (Machado and David, 1992; David and Syme, 1994; Stern et al., 1995). In combination with the new data showing (ca. 3 Ga) contamination of the Ruttan arc assemblage in the Leaf Rapids–Rusty Lake domain, these data extend to the north the rocks apparently affected by Archean crustal recycling during the evolution of arc magmatism in the Trans-Hudson Orogen.

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