Crustal evolution in the source region of the Witwatersrand sediments, South Africa – evidence from quartz pebble and quartzite geochemistry

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Various hypotheses have been proposed for the evolution of the continental crust which incorporate different models of growth through geologic time. The most widely used and tested model is that of extensive growth by intracrustal melting, starting about 3.2 Ga ago (Taylor & McLennan, 1985). Ages of single, detrital zircons from various Witwatersrand stratigraphic horizons (Fig.1) indicate a general trend of decreasing ages of source rocks from about 3.2 to 3.1 Ga for the Dominion Reef to less than 2.8 Ga for the Ventersdorp Contact Reef (VCR). A small number of older zircons with ages between 3.2 and 3.5 Ga occur in most sediments. There also appears to exist a gap in zircon ages at about 3.26 Ga indicating the end of an older tectonic cycle. A major new cycle of crustal evolution appears to have started at about 3.1 to 3.0 Ga, judging from the appearance of large numbers of detrital zircons of that age in Witwatersrand sediments (Barton, E.S. and Hallbauer, D.K., unpublished data).

Evidence for crustal evolution in the Witwatersrand source region is also available from a different avenue, the geochemistry of quartz. On average, quartz is the major component of Witwatersrand sediments and quartz pebbles of the 'vein quartz' type are a prominent component of most conglomerate horizons.

More than 200 single pebbles from different reefs and quartz from some primary sources have been analysed for trace elements by neutron activation analysis, and the results evaluated statistically. Following the pioneering work by Ljakhovich (1991) it was also assumed that the trace element distribution in Witwatersrand quartz pebbles mimics that of the parent rock or primary environment, respectively.

In his work, Ljakhovich presented trace element data on 50 'mantle granitoids' and 280 'intrusive, crustal granitoids'. By examing various element combinations it was found that the distribution of granitoid/quartz types show the best discrimination and genetic asociation in a Cr–Cs–Co ternary diagram with the 'intrusive, crustal granitoids' clustering towards the Cs apex and the 'mantle granitoids' trending to a field between the Co and Cr apices. 22 samples of quartz from veins located in the Murchison and Barberton greenstone belts, South Africa, plotted in a tight field close to the Cr apex. Based on these distributions, a general model of quartz composition and ternary diagram for 'greenstone-type vein quartz', 'intrusive, crustal granitoid-type' and 'mantle granitoid-type' quartz is proposed (Fig.2).

Plotting and analysing the data from Witwatersrand quartz pebbles showed trends

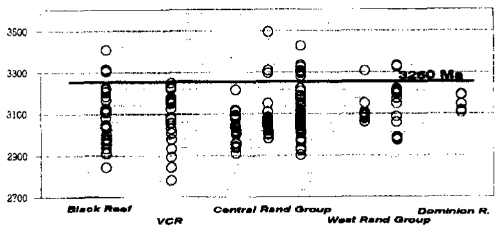

FIG. 1. Ages of detrital zircons, Witwatersrand Basin (various authors).

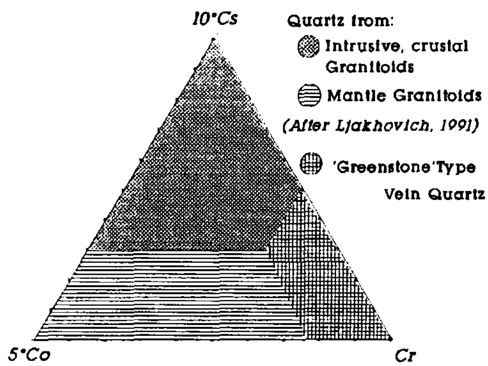

FIG. 2. Classification of quartz by Cr–Cs–Co contents.

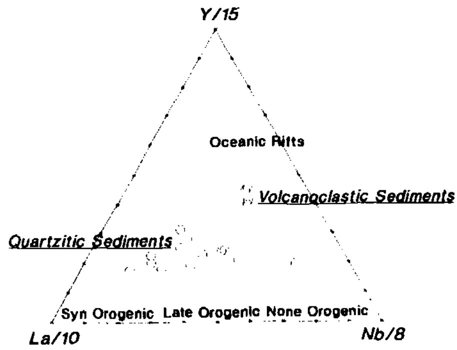

FIG. 3. Geotectonic diagram for various VCR sediments (after Lecolle *et al.*, 1991.

consistent with a crustal evolution model. The majority of pebbles from 'older' reefs, the Steyn Reef, Vaal Reef and Carbon Leader Reef plot preferably either in the 'mantle' or 'greenstone' field, whereas most pebbles from the 'younger' VCR plot in the 'crustal' and 'greenstone' parts of the ternary diagram. Further investigations also revealed that the majority of pebbles from the 'mantle' field show a REE distribution pattern without a negative Eu anomaly, consistent with an older, Archaean origin (Taylor & McLennon, 1985). Quartz pebbles that plot in the 'crustal' field have a well developed, negative Eu anomaly, pointing to partial melting and crustal evolution. Samples from the 'greenstone' area usually contain both REE distribution types. Other trace element combinations such as Sc–La–Th show a similar strong separation between quartz pebbles from the 'older' (Central Rand Group) and the 'younger' VCR horizon.

In some geochemical models of tectonomagmatic associations various combinations of trace elements are proposed to indicate the type of geotectonic environment of formation (Wood, 1980; Lecolle *et al.*, 1991) or differentiation trends (El Bouseily & El Sokkary, 1985). When applied to Witwatersrand sediments, the relevant geotectonic plots indicate an active margin environment in the synorogenic to late orogenic domains for the source rocks (Fig. 3). The differentiation trends, shown by the distribution of Sr, Rb and Ba, indicate normal granites to 'anomalous' metasomatically altered granites as sources for Witwatersrand sediments.

The geochemical observations and data from quartzitic sediments and and quartz pebbles thus support the general model of crustal evolution by Taylor & McLennon. Starting at about 3.2 Ga, a change from sources with a mantle signature to source rocks of a more granodioritic nature is evident. A plate tectonic environment in accordance with the model proposed by Winter (1987) is also supported by the geochemical data of quartz and quartzitic sediments. No evidence could be found that the 'extensive fluid activity' postulated by Phillips and Law (1994) for the metamorphic phase of the Witatersrand sediments, significantly affected the trace element composition and recrystallization of quartz pebbles.

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