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SCANNING ELECTRON MICROSCOPY OF QUARTZ IN PRECAMBRIAN CHERTS AND DOLOMITES FROM SOUTHERN AFRICA

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Abstract—Scanning electron microscopic (SEM) examination of the quartz isolated from chert of Transvaal and Swaziland, of 2000 and 3400 million year (MY) ages, respectively, in southern Africa revealed marked differences in quartz morphology. Well-defined individual euhedral quartz crystals, with polyhedral triple-point faces, were clearly evident on freshly fractured Transvaal chert surfaces as well as with the quartz isolates from the chert. The morphology and coarseness suggest crystal growth with little, if any, metamorphism; however, the $\delta^{18}O$ values of 23.8–24.1‰ suggest crystallization temperatures of perhaps 40–45°C. In contrast, fracture surfaces of the older, strongly metamorphosed Swaziland cherts revealed a high degree of grain intergrowth which inhibited fracture between quartz grains. Quartz isolates from these showed strongly interlocked quartz crystal clusters and elongated chips of quartz with poorly defined irregular faces. Intercalation of mineral veins in the cherts on a mm scale and the intergrown character of the quartz grain boundaries provide evidence that the latter cherts have been strongly metamorphosed and recrystallized, in keeping with 14.6–15.1‰ $\delta^{18}O$ values, corresponding to 80°C fractionation with water. The SEM micrographs of the fine quartz (1–10 μm) isolated from the Otavi dolomite formation of the 700-MY Damara System and from the 2000-MY Transvaal Dolomite Series revealed well-defined subhedral and euhedral quartz crystals of small size which, together with the 26.9–27.8‰ and 23.8‰ $\delta^{18}O$ values, respectively, indicate that these dolomites have been affected little, if any, by post-depositional metamorphism; their crystallization temperatures fall in the range of 25–30 and 40–45°C, respectively.

Key Words—Chert, Crystallization, Dolomite, Morphology, Metamorphism, Quartz.

INTRODUCTION

The objective of this paper is to describe the morphology of Precambrian cherts and quartz isolates of cherts and dolomites, in order to relate morphology to post-depositional crystallization temperature and metamorphism. Precambrian cherts and dolomites from the South African stratigraphic column (Haughton, 1969), with a wide range in age (from 650+ to 3400 million years, MY), have a wide variation in the morphology of the quartz grains therein, oxygen isotopic ratios ($\delta^{18}O$ values) and degree of metamorphism. Possible metamorphism can also be assessed from the degree of association of these materials with volcanic intercalations shown by the presence of veins of impurities on a mm scale.

Some of the oldest rocks thus far found belong to the Swaziland System which is divided into two Series, viz. the Onverwacht and Fig Tree. The Onverwacht consists mainly of basic and acid lavas, conformably overlain by the Fig Tree Series which is made up of shale, banded ironstone, graywacke and trachyte lavas (Van Eeden, 1972). According to isotopic determinations (Van Niekerk, 1968) on the acid lava, the age is approximately 3400 MY. Detailed work on the Onverwacht series led to its subdivision into three stages, the lower or Theespruit Stage, the middle or Komati River Stage, and the upper or Hooggenoeg Stage (Viljoen and Viljoen, 1967). Cyclic deposition is an outstanding feature of the sequence, and a complete cycle starts with basic and ultrabasic lavas followed by tuff and then chert. The entire Onverwacht sequence is approximately 11,000 m thick.

The Transvaal System (2000+ MY) is divided into three series, the Black Reef consisting mainly of conglomerate, quartzite, shale, lava and tuff, followed by the Dolomite Series consisting mainly of dolomite, chert and banded ironstone, and the Pretoria Series comprised of quartzite, shale, tillite, banded ironstone and andesitic lava (Van Eeden, 1972). Uncertainty still exists as to the degree of metamorphism that has influenced the dolomite and chert of the Dolomite Series.

The Otavi dolomite of the Damara System (650+ MY) resulted from deposition of limestone and calcareous algae in shallow seas of now South West Africa and field evidence indicates that volcanic metamorphism did not affect these dolomites.

MATERIALS

Cherts from the Onverwacht Series (group) of the Swaziland System were sampled (le Roux et al., 1975) at three localities in the Barberton Mountain range, Transvaal, South Africa:

*No. SC*1, red colored chert, from the Komati River Stage (formation), near the town Steynsdorp; south latitude 26°10′, east longitude 31°01′.

*No. SC*2, green colored chert, from the Hooggenoeg Stage, along the Badplaas–Havelock road; south lati-

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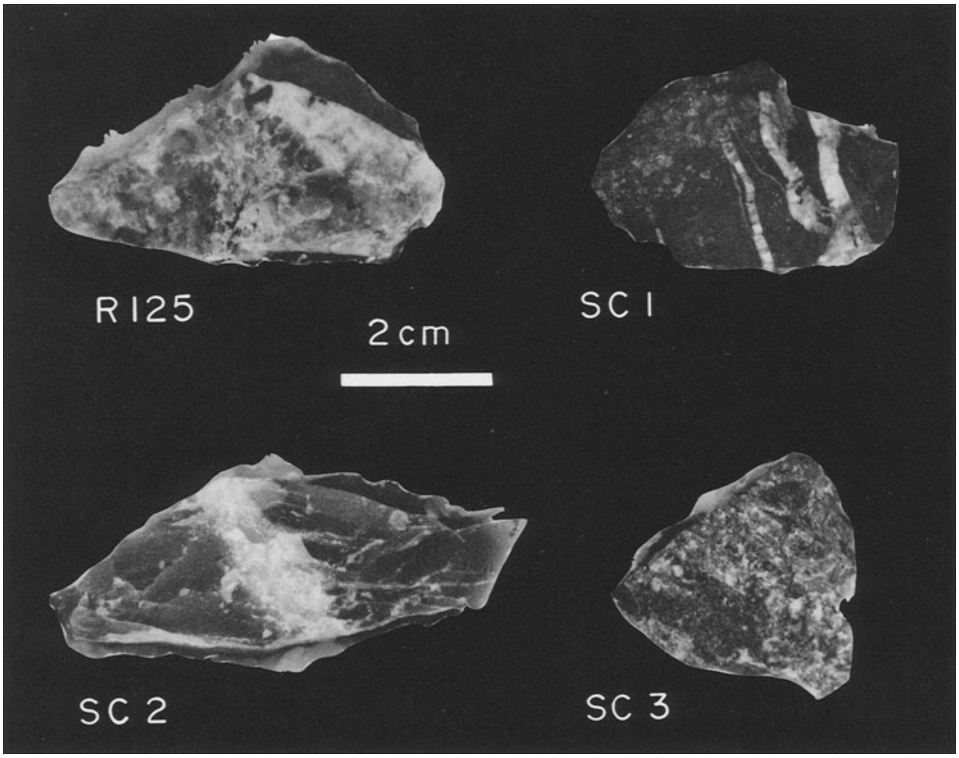

Fig. 1. Untreated samples of Transvaal chert (R125) and Swaziland cherts (SC1, red; SC2, green; and SC3, grey). The secondary veins present in samples SC1 and SC2 are clearly shown.

tude 26°04′, east longitude 31°01′. In this Stage the felsic lavas are massive light greenish rocks and in places contain pillow-structures with spherulites and fine-grained amygdales (Viljoen and Viljoen, 1969). These rocks are generally altered, commonly strongly silicified. According to Viljoen (personal communication) there appears to be a genetic relationship between the cherts and the felsic lavas; much of the silica necessary for the formation of the cherts appears to have been derived largely from the felsic lava just after extrusion. A radiometric (U–Pb) age determination on zircons from the upper felsic zone of this formation has yielded an age of 3360 MY (Van Niekerk, 1968).

*No. SC*3, dark grey colored chert of the Theespruit Stage near the Komati River; south latitude 26°02′, east longitude 31°03′. The felsic lavas are also closely associated with chert layers. In places black carbonaceous and siliceous shale zones are found within the chert bands, with the remains of primitive life forms (Engel et al., 1968; Brooks et al., 1974).

A representative chert and dolomite from the Transvaal System was sampled near Pretoria:

*No. R*125, light colored chert from a band in the massive Dolomite Series, south latitude 25°52′, east longitude 28°15′.

*No. R*124, dark colored dolomite from the Dolomite Series, south latitude 25°51′, east longitude 28°08′.

Representative samples of dolomite from the Damara System (Otavi Formation) were sampled at two localities in South West Africa.

*No. RS*13, light grey colored dolomite near Otavi, south latitude 19°42′, east longitude 17°25′.

*No. RS*12, light grey colored dolomite near Okabongora, south latitude 19°42′, east longitude 17°55′.

EXPERIMENTAL PROCEDURES

Quartz isolation

Samples were gently crushed (after hand-picking to exclude veins of impurities, present in the samples SC1 and SC2; Figure 1) to pass a 2-mm screen. The screened samples were pretreated with boiling 6 N HCl before isolation of the quartz by the sodium pyrosulphate fusion–hexafluorosilicic acid method [Syers et al. (1968) as modified by Sridhar et al. (1975) and Jackson (1974)]. The purity of the quartz isolates was checked by X-ray powder diffraction.

Scanning electron microscopy

The samples were lightly crushed. The freshly fractured chips and quartz isolates were mounted on 9-mm diam. carbon stubs with double-stick tape. The mounted samples were then coated with a film of Au–Pd alloy several hundred Ångströms thick evaporated in vacuum at multiple angles of incidence to form an electrically conductive surface. The scanning electron

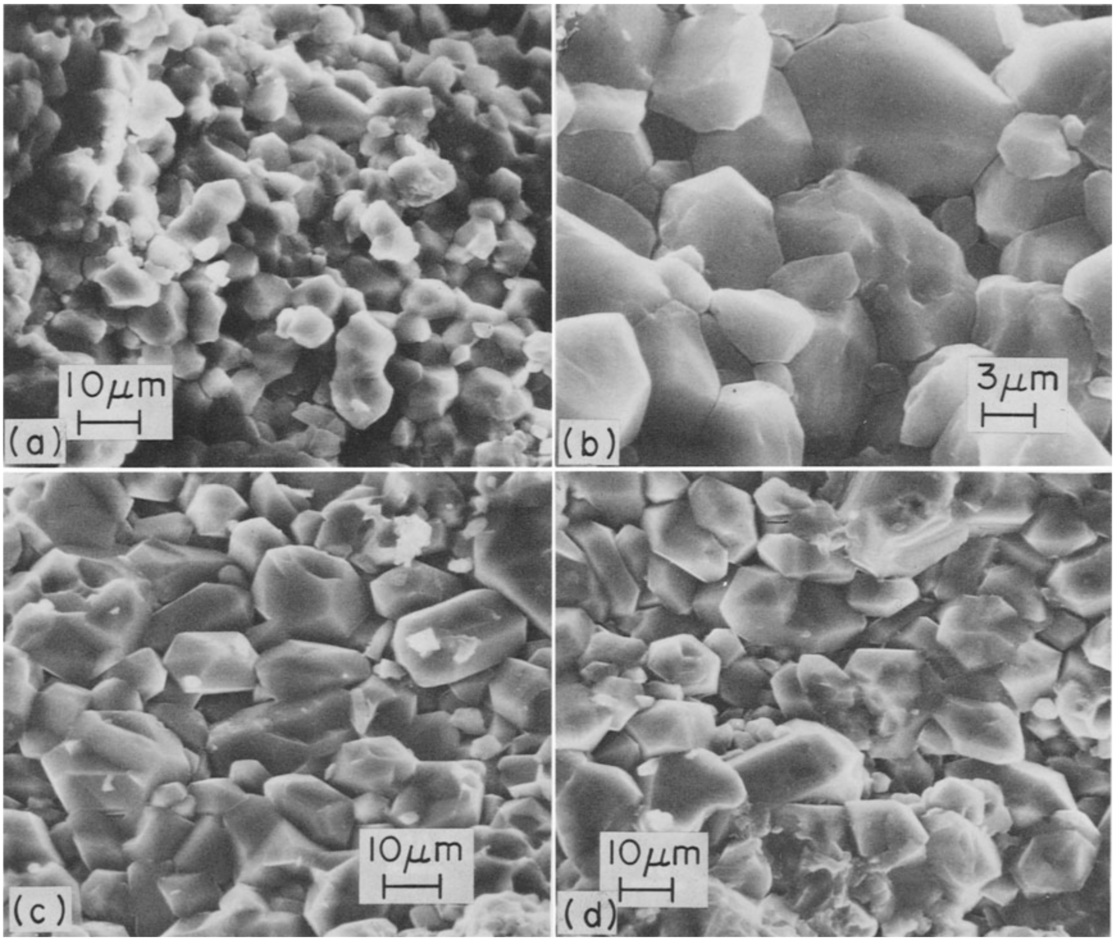

Fig. 2. Scanning electron micrographs of freshly fractured surface of Transvaal (2000 MY) chert with $\delta^{18}O$ of 24.1‰: (a) crystalline quartz grains; (b) closer look at crystalline quartz grains showing detail of closely intergrown grains; (c) and (d) quartz grains with near polygonal triple-point texture (Spry, 1969), (d) showing no change after HCl treatment.

microscope (SEM) observations were done with a JEOL JSM-50A Scanning Electron Microscope with X-ray emission detector.

RESULTS AND DISCUSSION

Quartz morphology

The untreated chert samples show prominent banding, particularly visible in the Swaziland cherts SC1 and SC2 (Figure 1), indicative of secondary intrusions.

The freshly fractured surfaces of Transvaal chert (Sample R125) reveal, by scanning electron microscopy (SEM), euhedral quartz crystals with well-defined faces (Figures 2a–c). The sharp crystal faces suggest they have polygonal triple-point texture (Spry, 1969, pp. 41–42). The X-ray emission spectrum indicated only Si, which suggests that the specimens consist of relatively pure quartz grains. Pretreatment of a freshly fractured surface with 6 N HCl resulted in no visible change in the quartz morphology (Figure 2c, d).

The older, Swaziland cherts have markedly different fracture morphology (Figure 3). The Swaziland red chert (Sample SC1) fracture surface reveals a high degree of grain intergrowth which apparently inhibited fracture between well-defined euhedral quartz crystal faces (Figure 3a). The X-ray spectra showed a considerable amount of Fe present in addition to Si. A typical conchoidal fracture surface morphology is shown by the Swaziland green chert (Sample SC2, Figure 3b); X-ray spectra indicated relatively pure Si. The dark grey chert (Sample SC3) shows typical laminated fracture surfaces (Figures 3c). In addition to Si, the X-ray spectra showed strong peaks for Ca, K, Al and Fe (possibly present as coatings on quartz grains). The fracture surface morphology of these Swaziland cherts probably results from splitting of the strongly interlocked quartz grains in the clusters (Sayin and Jackson, 1975).

The whole quartz, chemically isolated from Transvaal and Swaziland cherts, also reveal marked SEM

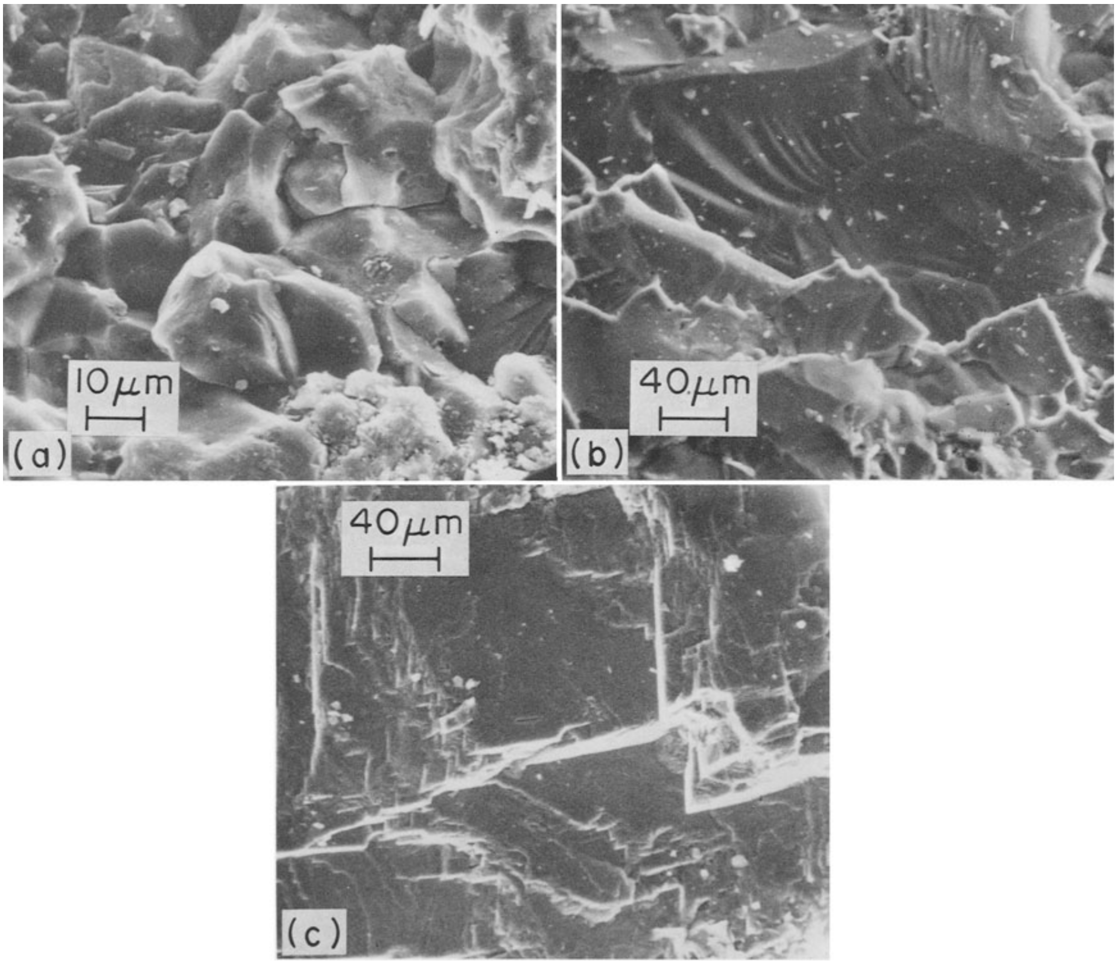

Fig. 3. Scanning electron micrographs of freshly fractured surfaces of Swaziland (3400 MY) cherts with $\delta^{18}O$ of 14.6–15.1‰: (a) red chert (SC1) showing irregular fracture surface; (b) green chert (SC2) showing typical conchoidal fracture; and (c) dark grey chert (SC3) surface showing coarse cleavage and lamination.

differences in the quartz morphology. In contrast, to the well-shaped single euhedral quartz particles (Figure 4a) or clusters of individual quartz crystals with well-defined polyhedral faces (Figure 4b) in the Transvaal quartz isolates (No. R125), the isolates from the older, Swaziland chert (No. SC3) reveal intergrown quartz crystal clusters and flakes or chips of quartz (Figure 5a) with poorly defined irregular faces. At successively higher magnifications (Figures 5b–d) the strong interlocking of quartz grains and the loss of clearly defined grain boundaries are clearly evident.

The contrasting quartz morphology of the 2000-MY Transvaal chert and the 3400-MY Swaziland cherts, together with the intercalated veins (Figure 1), strongly suggests that the latter cherts have been metamorphosed by close proximity to the volcanic lava intercalations and recrystallized post-depositionally to create strongly interlocked quartz grains with diffuse boundaries.

For comparative purposes the 1–10-μm quartz isolated from the Otavi (R13) and Transvaal (R124) dolomites were also examined. The well-defined subhedral and polyhedral quartz crystals present in these dolomites (Figures 6a–c) agree with field evidence that they have been relatively little affected by post-depositional metamorphism.

Isotopic data

The oxygen isotopic ratios (expressed as $\delta^{18}O$ values) for the quartz in chert and dolomite from Precambrian rocks (Table 1) vary from about 15 to 28‰. Such variation has been attributed mainly to the temperature of oxygen fractionation between silica and water (Knauth and Epstein, 1976). The $\delta^{18}O$ values range from 26.9 to 27.8‰ for quartz from approximately 700 MY Otavi dolomite, corresponding to crystallization at approximately 25–30°C; the range of 23.8–24.1‰ for those from 2000-MY Transvaal System dolomite and chert bands

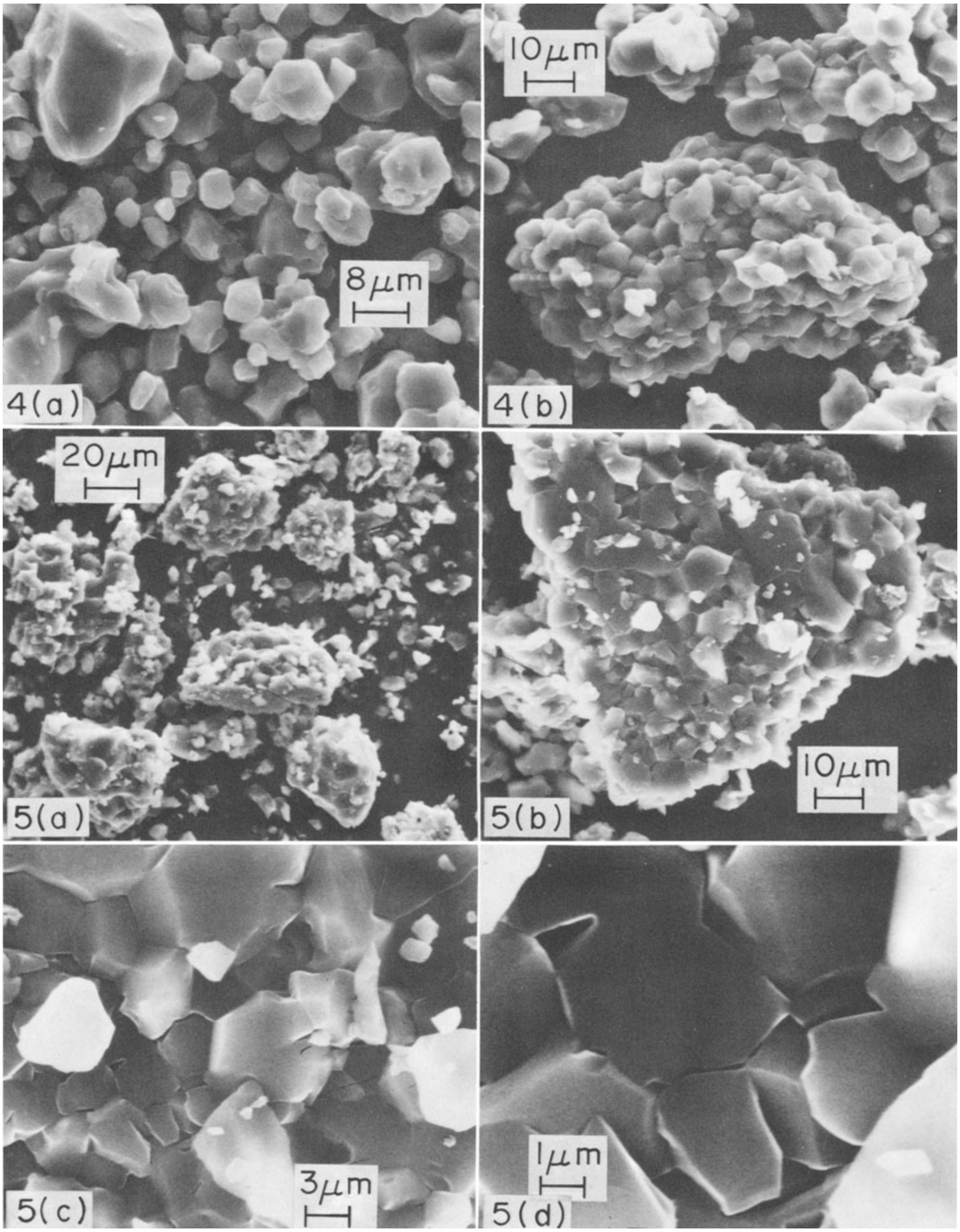

Fig. 4. Scanning electron micrographs of whole quartz isolated from Transvaal chert showing (a) polygonal crystals and (b) crystal clusters of polygonal triple-point texture.

Fig. 5. Scanning electron micrographs of whole quartz isolated from Swaziland dark grey (SC3) chert with $\delta^{18}O$ of 14.6‰: (a) clusters of strongly interlocked quartz particles with many irregularly shaped clusters or chips; (b), (c) and (d) clusters at progressively increasing magnifications with the clearly shown strong interlocking growth of the quartz grains, indicative of strong metamorphism.

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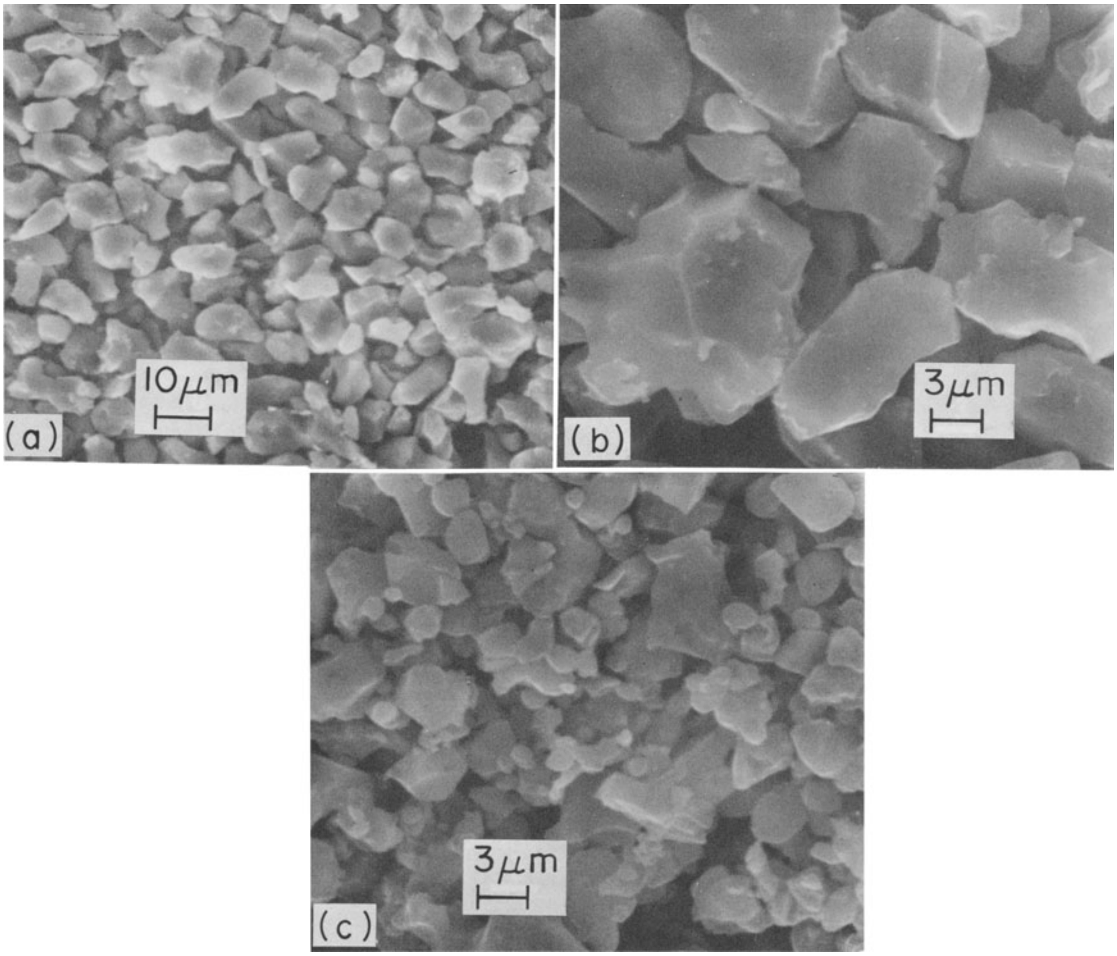

Fig. 6. Scanning electron micrographs of 1–10-μm quartz isolated from Precambrian dolomites: (a) and (b) polyhedral crystals from 700 MY Otavi dolomite (RS13), with $\delta^{18}O$ of 27.8‰; (c) partially polyhedral and subhedral crystals from 2000 MY Transvaal dolomite (R124), with $\delta^{18}O$ of 23.8‰.

(Dolomite Series) may suggest crystallization at 40–45°C; and the 14.6–15.1‰ range for quartz from the 3400-MY Onverwacht cherts of the Swaziland System may correspond to crystallization temperatures of 80°C or more (Knauth and Epstein, 1976, p. 1103).

Quartz from igneous and metamorphic rocks throughout the world has oxygen isotopic ratios predominantly in the range $\delta^{18}O$ = 8–14‰ (Clayton and Epstein, 1958; le Roux et al., 1977). In contrast, typical $\delta^{18}O$ values for quartz isolated from Phanerozoic cherts of U.S.A. range from 25 to 32‰ (Clayton and Epstein, 1958; Degens and Epstein, 1962; Jackson et al., 1971). Similarly lower ratios for quartz of ancient cherts (including cherts from South Africa, Swaziland System; $\delta^{18}O$ = 13–24‰ for 3100–1700-MY-old rocks, respectively) were reported earlier (Perry and Tan, 1972). The possibility that these lower isotopic ratios of ancient cherts may have resulted partly from metamorphosis, i.e., formation at higher temperatures (70°C ≃ 15‰) was suggested by Garlick (1974, p. 416). Perry and Tan (1972) suggested that if the highest $\delta^{18}O$ values of these ancient chert and carbonate rocks are primary, the $\delta^{18}O$ of the ocean had probably increased by about 15‰ since their deposition. Their highest observed $\delta^{18}O$ value for chert in these rocks is about 17‰ lower than the value for SiO_2 freshly precipitated from modern ocean water (Mopper and Garlick, 1968). However, they also conclude from their data "that post-depositional alteration has lowered $\delta^{18}O$ SiO_2 values by 5 to 8‰, and it remains possible that all $\delta^{18}O$ values are somewhat altered." The quartz δ values of our middle and late Precambrian dolomites and chert (Table 1) are similar to the range for quartz of Phanerozoic cherts (Degens and Epstein, 1962; Sridhar et al., 1975) and could have been crystallized at comparable geothermal temperatures at shallow burial. The SEM morphologies (Figures 2, 4 and 6) are also similar (Sayin and Jackson, 1975). The similarities in isotopic ratios for quartz of cherts and

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Table 1. Content and oxygen isotope abundance of quartz from selected Precambrian cherts dolomites*

Sample			Fraction (μm)	Content of fraction in sample (%)	Quartz content of fraction (%)	$\delta^{18}O$§ (‰)
No.	Age† (MY)	Source rock				
Dolomites						
RS12	700	Damara (Otavi)	1–10	1.9	16.6	26.9
RS13	700	Damara (Otavi)	1–10	1.8	17.8	27.8
R124	2000	Transvaal	1–10	1.7	13.6	23.8
Cherts						
R125	2000	Transvaal	w.s.‡	—	91.2	24.1
SC1	3400	Swaziland (red)	w.s.	—	91.1	15.1
SC2	3400	Swaziland (green)	w.s.	—	80.2	—
SC3	3400	Swaziland (dark grey)	w.s.	—	82.1	14.6

* Data from le Roux *et al.* (1975).
† Approximate, million years.
‡ w.s., whole sample, after quartz isolation treatment given in the procedure.
§ Oxygen isotopic ratio in conventional per mil terms [parts per thousand, ‰, relative to Standard Mean Ocean Water, SMOW, $\delta^{18}O$; Clayton and Mayeda (1963)].

dolomites from 700- to 2000-MY-old-formations showing no evidence for metamorphism to those of Phanerozoic cherts suggest that age as such has little or no effect on oxygen isotopic ratios of silt-size or coarser quartz; the principal control appears therefore to be temperature (Clayton et al., 1968; Knauth and Epstein, 1976; Yeh and Savin, 1976). The Swaziland cherts with lower numbers have interlocking crystals (Figure 5) and intruded volcanic rock veins (Figure 1), both of which are consistent with oxygen isotopic lightening by exchange with water under metamorphism at elevated temperature.

CONCLUSIONS

1. Typical euhedral crystals and oxygen isotopic ratios ($\delta^{18}O$ = 27–28‰) occur in 700-MY-old Otavi dolomite, comparable to quartz from Phanerozoic dolomites (Sridhar et al., 1975). This is remarkable when related to the drift of Africa down across the South Pole (Drewry et al., 1974) and back.

2. Growth of interlocking quartz crystals is typical of 3400-MY-old quartz from Swaziland chert which has lower oxygen isotopic ratios ($\delta^{18}O$ = 14.6–15.1‰), consistent with a hypothesis of heating and oxygen isotopic exchange with meteoric water at the higher temperatures during metamorphic rock intrusions.

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REFERENCES

Brooks, J., Muir, M. D. and Shaw, G. D. (1974) Chemistry and morphology of Precambrian microorganisms: *Nature* **244,** 215–217.

Clayton, R. N. and Epstein, S. (1958) The relationship between $^{18}O/^{16}O$ ratios in coexisting quartz, carbonate and iron oxides from various geological deposits: *J. Geol.* **66,** 352–373.

Clayton, R. N. and Mayeda, T. K. (1963) The use of bromine pentafluoride in the extraction of oxygen from oxides and silicates for isotopic analyses: *Geochim. Cosmochim. Acta* **27,** 43–52.

Clayton, R. N., Muffler, L. J. P. and White, D. E. (1968) Oxygen isotope study of calcite and silicates of the River Ranch No. 1 well, Salton Sea geothermal field, California: *Am. J. Sci.* **266,** 968–979.

Degens, E. T. and Epstein, S. (1962) Relation between O^{18}/O^{16} ratios in coexisting carbonates, cherts and diatomites: *Bull. Am. Assoc. Petrol. Geol.* **46,** 534–542.

Drewry, G. E., Ramsay, A. T. S. and Smith, A. G. (1974) Climatically controlled sediments, the geomagnetic field, and trade wind belts in Phanerozoic time: *J. Geol.* **82,** 531–553.

Engel, A. E. J., Nagy, B., Nagy, L. A., Engel, C. G., Kremp, G. O. W. and Drew, C. M. (1968) Alga-like forms in Onverwacht Series, South Africa: oldest recognized life-like forms on earth: *Science* **161,** 1005–1008.

Garlick, G. D. (1974) The stable isotopes of oxygen, carbon and hydrogen in the marine environment: In *The Sea—Ideas and Observations on Progress in the Study of the Seas.* Vol. 5—*Marine Chemistry* (Edited by Goldberg, E. G.) p. 393. John Wiley, New York.

Haughton, S. H. (1969) *Geological History of Southern Africa:* Geol. Soc. South Africa, 535 pp.

Knauth, L. P. and Epstein, S. (1976) Hydrogen and oxygen isotopic ratios in nodular and bedded cherts: *Geochim. Cosmochim. Acta* **40,** 1095–1108.

Jackson, M. L. (1974) *Soil Chemical Analysis Advanced Course*, 9th printing: published by the author, Madison, WI.

Jackson, M. L., Levelt, T. W. M., Syers, J. K., Rex, R. W., Clayton,

R. N., Sherman, G. D. and Uehara, G. (1971) Geomorphological relationships of tropospherically derived quartz in the soils of the Hawaiian Islands: *Soil Sci. Soc. Am. Proc.* **35,** 515–525.

le Roux, J., Clayton, R. N., Mayeda, T. K. and Jackson, M. L. (1975) Oxygen isotope abundance in quartz from Precambrian cherts and dolomites of southern Africa: (abs.) *Eos Trans. Am. Geophys. Union* **56,** 605.

le Roux, J., Clayton, R. N. and Jackson, M. L. (1977) Oxygen isotope abundance in quartz fine silt from sediments and soils of southern Africa: *Geochim. Cosmochim. Acta* submitted for publication.

Mopper, R. and Garlick, G. D. (1968) Oxygen isotope fractionation between biogenic silica and ocean water: (abs.) *Trans. Am. Geophys. Union* **49,** 336.

Perry, E. C. and Tan, F. C. (1972) Significance of oxygen and carbon isotope variations in early Precambrian cherts and carbonate rocks of southern Africa: *Bull. Geol. Soc. Am.* **83,** 647–664.

Sayin, M. and Jackson, M. L. (1975) Scanning electron microscopy of cherts in relation to the oxygen isotopic variation of soil quartz: *Clays & Clay Minerals* **23,** 365–368.

Spry, A. (1969) *Metamorphic Textures:* Pergamon Press, Oxford.

Sridhar, K., Jackson, M. L. and Clayton, R. N. (1975) Quartz oxygen isotopic stability in relation to isolation from sediments and diversity of source: *Soil Sci. Soc. Am. Proc.* **39,** 1209–1213.

Syers, J. K., Chapman, S. L. and Jackson, M. L. (1968) Quartz isolation from rocks, sediments and soils for determination of oxygen isotopic composition: *Geochim. Cosmochim. Acta* **32,** 1022–1025.

Van Eeden, O. R. (1972) An explanation of the 1:1,000,000 map of the geology of South Africa: Special Publ. No. 18, Government Printer, Pretoria, South Africa, 85 pp.

Van Niekerk, C. B. (1968) The suitability of extensive acid rocks for U-Pb radiometric dating: Ph.D. thesis, University of Cape Town.

Viljoen, M. J. and Viljoen, R. P. (1967) A reassessment of the Onverwacht Series in the Komati River Valley: *Inf. Circ. Econ. Geol. Res. Unit*, **36,** University Witwatersrand.

Viljoen, M. J. and Viljoen, R. P. (1969) Evidence for the existence of a mobile extrusive peridotitic magma from the Komati Formation of the Onverwacht Group: In *Upper Mantle Sym. Spec. Publ. Geol. Soc. S. Afr.*, Vol. 2, pp. 87–112.

Yeh, H. W. and Savin, S. M. (1976) The extent of oxygen isotope exchange between clay minerals and sea water: *Geochim. Cosmochim. Acta* **40,** 743–748.

Резюме- Изучение с помощью развертывающего электронного микроскопа /рэм/ образцов кварца,выделенных из кремнистых пород Трансвааля и Свазиленда в Южной Африке,возрастом соответственно 2000 и 3400 млн лет,обнаружило примечательные различия в морфологии кварца. Хорошо очерченные отдельные идиоморфные кристаллы кварца,с полиэдрическими трех-точечными гранями были отчетливо видны на свеже-расколотых поверхностях Трансваальских кремнистых пород,а также на образцах кварца,выделенных из них. Морфология и крупность кристаллов предполагают их рост без влияния или со слабым влиянием метаморфизма;однако значения $\delta^{18}O$ равные 23,8-24,1% предполагают температуру кристаллизации возможно 40-45°C. В противоположность этому поверхности расколов в более древних сильно метаморфизованных кремнистых породах Свазиленда обнаруживают высокую степень прорастания зерен,что препятствовало образованию трещин между зернами кварца. Выделенный из этих пород кварц обнаружил сильно сросшиеся пучки кристаллов и вытянутые пластинки кварца с плохо очерченными неровными гранями. Минеральные жилы в кремнистых породах в мм масштабе,сросшийся характер граней кварца доказывают,что эти кремнистые породы были сильно метаморфизованы и перекристаллизованы,сохраняя значения $\delta^{18}O$ 14,6-15,1%,соответствующие температуре 80°C ректификации водой. Микроснимки рэм мелкозернистого кварца /1-10мм/,выделенного из формации доломита Отави системы Дамара возрастом 700 млн лет и из Трансваальской доломитной серии возрастом 200 млн лет обнаружили хорошо очерченные гипидиоморфные и идиоморфные кристаллы кварца небольшого размера,которые,вместе со значениями $\delta^{18}O$ равными 26,9-27,8% и 23,8% соответственно,показывают,что эти доломиты подверглись незначительному постседиментационному метаморфизму или не испытали его совсем;их температуры кристаллизации колеблются в пределах соответственно 25-30 и 40-45°C.

Kurzreferat- Scanning electron microscopic (SEM) Untersuchungen von Quartz, 2000 bzw. 3400 Mio Jahre alt,der von Hornsteinen aus Transvaal und Swaziland isoliert wurde, brachte ausgeprägte Unterschiede in Quartzmorphologie hervor. Gut definierte, einzelne, idiomorphe Quartzkristalle, mit polyedrischen Tripelpunktflächen waren, an frisch gebrochenen Transvaal Hornsteinoberflächen,sowohl wie an vom Hornstein isolierten Quartz, sehr klar zu sehen. Die Morphologie und die grobe Qualität der Kristalle schlagen Kristallwachstum mit wenig oder garkeinem Metamorphismus vor. Die $\delta^{18}O$ Werte von 23,8-24,1 o/oo schlagen jedoch Kristallisierungstemperaturen von etwa 40-45°C vor. Bruchflächen der älteren, stark metamorphosierten Swaziland Hornsteinen dagegen, zeigen einen hohen Grad von Faserdurchwachsung, welches Brüche zwischen Quartzfasern verhindert. Quartz, der von diesem Gebiet isoliert wurde, zeigte stark ineinandergreifende Quartzdrusen und verlängerte Quartzgranulate mit schlecht definierten, irregulären Flächen.Einlagerung von Mineralvenen in die Hornsteine,im mm Maßstab, und der durchwachsene Cha-

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rakter der Quartzfasergrenzen, beschaffen Beweise, daß die letzteren Hornsteine stark metamorphosiert und rekristallisiert waren, was mit den 14,6-15,1 o/oo$\delta^{18}O$ Werten übereinstimmt und der bei 80°C stattfindenen Fraktionation mit Wasser entspricht.Die SEM Mikrographien des feinen Quartzes (1-10 μm), isoliert aus der Otavi Dolomitformation des 700 Mio Jahre alten Damara Systems und aus der 2000 Mio Jahre alten Dolomiten Serie, zeigten gut definierte, hypidiomorphe und idiomorphe, kleine Quartzkristalle, welche zusammen mit den 26,9-27,8 o/oo bzw. 23,8 o/oo $\delta^{18}O$ Werten anzeigen, daß diese Dolomiten wenig oder garnicht von Nach-Ablagerungsmetamorphismus beeinflußt wurden. Ihre Kristallisierungstemperaturen fallen in den Bereich von 25-30° bzw. 40-45°C.

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