The development and environmental significance of the dry valley systems (*mekgacha*) in the Kalahari, central southern Africa

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Bibliography

Abdel-Rahman M.A. (1975) Quantitative analysis of some geological relationships of drainage networks in the Mula area, southeast Spain, Unpublished Ph.D. Thesis, University of Sheffield, 360pp.

Abdel-Rahman M.A. (1978) "A statistical method for determining the orientational relationships between geological variables", in M. Podwysocki and J.L. Earle (eds), Proceedings of the Second International Conference on Basement Tectonics (Denver, Colorado), Basement Tectonics Committee Publications 2:486-490.

Abdel-Rahman M.A. and Hay A.M. (1981) Statistical analysis of multi-modal orientation data, Proceedings of the 3rd International Conference on Basement Tectonics (Durango, Colorado), Basement Tectonics Committee Publications 3:73-86.

Abrahams A.D. and Flint J.J. (1983) Geological controls on the topological properties of some trellis drainage networks, Bulletin of the Geological Society of America 94:80-91.

Acres B., Blair Rains A., King R., Lawton R., Mitchell A. and Rackham L. (1985) African dambos: their distribution, characteristics and use, Zeitscrift für Geomorphologie Supplementband 52:63-86.

Albat H. (1978) The geology of the Kalahari Beds of northeastern South West Africa, De Beers Prospecting South West Africa (pty) Ltd, Unpublished report, Windhock. 12pp.

Aldiss D.T. (1984) Comments on the geology of the Okwa valley near the Ghanzi-Lobatse road (2221B), Ghanzi District, Botswana Department of Geological Survey Unpublished report DTA/8/84, Lobatse. 5pp.

------ (1985) The geology of the Phitsane area, Botswana Department of Geological Survey Bulletin 28, Gaborone. 106pp + maps.

------ (1987*a*) A record of stone axes near Tswaane borehole, Ghanzi District, Botswana Notes and Records 19:41-43.

------ (1987*b*) Outline description of the geology of the Hanchai area - a brief description of quarter degree sheets 2221A-D, 2222A and 2222C in Ghanzi District, Botswana Department of Geological Survey Kalahari Series Report 1, Unpublished, Lobatse. 25pp.

------ (1988) The Pre-Cainozoic geology of the Okwa valley near Tswaane borehole - an explanation of part of quarter degree sheet 2221B, Botswana Department of Geological Survey Bulletin 34, Gaborone. 50pp.

Aldiss D.T., Tombale A.R., Mapeo R.M.B. and Chiepe M. (1989) The geology of the Kanye area - an explanation of quarter degree sheet 2425C, Botswana Department of Geological Survey Bulletin 33, Gaborone. 170pp.

Aldiss D.T. and Carney J.N. (1992) The geology and regional correlation of the Proterozoic Okwa Inlier, western Botswana, Precambrian Research 56:255-274.

Alexander J.E. (1838) An expedition of discovery into the interior of Africa, H. Colburn, London.

Alison M.S. (1899) On the origin and formation of pans, Transactions of the Geological Society of South Africa 4, 159pp.

Andersson C.J. (1856) Lake Ngami; or explorations and discoveries during four years wanderings in the wilds of south western Africa, Hurst and Blackett Publishers, London, 536pp. Reprinted 1967, C. Struik (pty) Ltd, Cape Town.

Andersson R.F.J. (1976) "Weather of the Okavango delta", in Proceedings of the symposium on the Okavango delta and its future utilisation, Botswana Society, Gaborone pp29-31.

Arad A. (1984) Relationship of salinity of groundwater to recharge in the southern Kalahari desert, Journal of Hydrology 71:225-238.

Arakel A.V. (1986) Evolution of calcrete in palaeo-drainages of the Lake Napperby area, central Australia, Palaeogeography, Palaeoclimatology and Palaeoecology 54:283-303.

------ (1991) Evolution of Quaternary duricrusts in Karinga Creek drainage system, central Australian groundwater discharge zone, Australian Journal of Earth Sciences 38:333-347.

Arakel A.V., Jacobson G., Salehi M. and Hill C.M. (1989) Silicification of calcrete in palaeodrainage basins of the Australian arid zone, Australian Journal of Earth Sciences 36:73-89.

Avigour A., Magaritz M. and Issar A. (1992) Pleistocene palaeoclimate of the arid region of Israel as recorded in calcite deposits along regional transverse faults and in veins, Quaternary Research 37(3):304-314.

Baillieul T.A. (1975) A reconnaissance survey of the cover sands in the Republic of Botswana, Journal of Sedimentary Petrology 45(2):494-503.

------ (1979) The Makgadikgadi pans complex of central Botswana, Bulletin of the Geological Society of America 90:133-136.

Baines T. (1864) Exploration in Southwest Africa, Longman, Greens and Co., London (Reprinted by Gregg International Publishers, Farnborough, Hampshire, 1968).

Baker V.R. (1980) Some terrestrial analogs to dry valley systems on Mars, NASA Technical Memo TM 81776:286-288.

------ (1982) The Channels of Mars, University of Texas Press, Austin, 198pp.

------ (1983) "Large scale fluvial palaeohydrology", in K.J. Gregory (ed) Background to Palaeohydrology, John Wiley, Chichester. pp 453-478.

------ (1985) "Models of fluvial activity on Mars", in M.J. Woldenberg (ed) Models in Geomorphology, Allen and Unwin, London. pp 287-312.

------ (1990) "Spring-sapping and valley network development, with case studies by R.C. Kochel, V.R. Baker, J.E. Laity and A.D. Howard", in C.G. Higgins and D.R. Coates (eds) Groundwater geomorphology: the role of subsurface water in earth-surface processes and landforms, Geological Society of America Special Paper 252, Boulder, Colorado. pp235-265.

Baker V.R., Pickup G. and Polach H.A. (1983) Desert palaeofloods in central Australia, Nature 301:502-504.

Baldock J.W., Hepworth J.V. and Marengwa B.S. (1976) Gold, base metals and diamonds in Botswana, Economic Geology 71:139-156.

Balfour D.J., Hegenberger W., Medlycott A.S. and Wilson K.J. (1985) Kimberlites near Sikereti, north-eastern South West Africa/Namibia, Communications of the Geological Survey of South West Africa/Namibia 1:69-77.

Bannister E. (1980) Joint and drainage orientation of south-west Pennsylvania, Zeitschrift für Geomorphologie 24(3):273-286.

Beaumont P.B., Van Zinderen Bakker E.M. and Vogel J.C (1984) "Environmental changes since 32,000 B.P. at Kathu pan, Northern Cape", in J.C. Vogel (ed) Late Cainozoic palaeoclimates in the southern hemisphere, A.A. Balkema, Rotterdam, pp329-338.

Belderson R.H. (1983) Comment: drainage systems developed by sapping on Earth and Mars, Geology 11:55.

Bell-Cross G. (1975) "The fishes", in D.W. Phillipson (ed) Mosi-oa-Tunya: a handbook to the Victoria Falls region, Longman Zimbabwe, Harare, pp185-197.

Berry B.J.L and Marble D.F. (1968) Spatial analysis: a reader in statistical geography, Prentice-Hall, New Jersey, 512pp.

Birkeland P.W. (1974) Pedology, weathering and geomorphological research, Oxford Univeristy Press, 285pp.

Blank H.R. and Tynes E.W. (1965) Formation of calcrete *in situ*, Bulletin of the Geological Society of America 76:1387-1392.

Boast R. (1990) Dambos: a review, Progress in Physical Geography 14:153-177.

Bond G. (1946) The Pleistocene succession around Bulawayo, Occasional Papers of the National Museum of Southern Rhodesia 12:104-115.

------ (1948) The direction of origin of the Kalahari Sands of Southern Rhodesia, Geological Magazine 85:303-315.

------ (1963) "Pleistocene environments in southern Africa", in F.C. Howell and F. Bourliere (eds) African ecology and human evolution, Viking, Chicago (2nd edition 1966), pp308-334.

------ (1967) "River valley morphology, stratigraphy and palaeoclimatology in southern Africa", in W.W. Bishop and J.D. Clarke (eds) Background to evolution in Africa, University of Chicago Press, Chicago and London, pp303-312.

------ (1975) "The geology and formation of the Victoria Falls", in D.W. Phillipson (ed) Mosi-oa-Tunya: a handbook to the Victoria Falls region, Longman Zimbabwe, Harare, pp19-48.

Boocock C. (1962) The Precambrian of Bechuanaland Protectorate, Unpublished Report of the Geological Survey of Bechuanaland, Gaborone.

------ (1966) The Karroo system in Bechuanaland, Botswana Department of Geological Survey Bulletin 2, Gaborone.

Boocock C. and Van Straten O.J. (1961) Note on the development of potable water supplies at depth in the central Kalahari, Records of the Geological Survey of Bechuanaland Protectorate 1957-58, Gaborone. pp11-14.

------ (1962) Notes on the geology and hydrology of the central Kalahari region, Bechuanaland Protectorate, Transactions of the Geological Society of South Africa 65:125-171.

Boulaine J. (1954) La sebkha de Ben Ziane et sa 'lunette' ou Bourellet exemple de complex morphologique formé par la dégradation éolienne des sols salés, Revue de Géomorphologique Dynamique 4:102-123.

Bowler J.M. (1973) Clay dunes: their occurrence, formation and environmental significance, Earth-Science Review 9:315-338.

------ (1986) Spatial variability and hydrological evolution of Australian lake basins: an analogue for Pleistocene hydrologic change and evaporite formation, Palaeogeography, Palaeoclimatology and Palaeoecology 54:21-41.

Brain C.K. (1957) Observations on the recent geological history of the Kalahari Gemsbok National Park, National Parks Board of South Africa, Pretoria, unpublished report 2pp.

Breyer J.I.E. (1982) Reconnaissance geomorphological terrain classification, Lower Boteti river, northern Botswana, ITC Journal 192-3:317-323.

Brook G.A. (1982) Stratigraphic evidence of Quaternary climatic change at Echo Cave, Transvaal, and a palaeoclimatic record from Botswana and north-eastern South Africa, Catena 9:343-351.

Brook G.A., Burney D.A. and Cowart J.B. (1990) Desert palaeoenvironmental data from cave speleotherms with examples from the Chihuahuan, Somali-Chalbi and Kalahari Deserts, Palaeogeography, Palaeoclimatology and Palaeoecology 76:311-329.

Brown D.S. (1980) Freshwater snails of Africa, and their medical importance, Taylor and Francis Ltd, London, 487pp.

Bruno S.A. (1985) "Pan genesis in the southern Kalahari", in D.G. Hutchins and A.P. Lynam (eds) The proceedings of a seminar on the mineral exploration of the Kalahari, Botswana Department of Geological Survey Bulletin 29, Gaborone. pp261-277.

Buckley D.K. (1984) Groundwater exploration at Lethlakeng, Botswana Department of Geological Survey Unpublished Report GS/DKB/9/84, Lobatse. 17pp.

Buckley D.K. and Zeil P. (1984) "The character of fractured rock aquifers in eastern Botswana", in Challenges in African Hydrology and Water Resources (Proceedings of the Harare Symposium July 1984), International Association of Hydrological Sciences Publication 144, pp25-36.

Bullock A. (1992) Dambo hydrology in southern Africa - review and reassessment, Journal of Hydrology 134:373-396.

Bunting J.A., Van De Graaff W.J.E. and Jackson M.J. (1974) Palaeodraianges and Cainozoic palaeogeography of the Eastern Goldfields, Gibson Desert and Great Victoria Desert, Western Australian Geological Survey Annual Report 1973, pp45-50.

Burke K. and Wells G.L. (1989) Trans-African drainage system of the Sahara: was it the Nile?, Geology 17:743-747.

Burt T.P and Gardiner A.T. (1982) The permanence of stream networks in Britain: some further comments, Earth Surface Processes and Landforms 7:327-332.

Burt T.P and Oldman J.C. (1986) The permanence of stream networks in Britain: further comments, Earth Surface Processes and Landforms 11:111-113.

Butterworth J.S. (1982) The chemistry of Mogatse Pan - Kgalagadi District, Botswana Department of Geological Survey Unpublished Report JSB/14/82, Lobatse. 15pp.

Butzer K.W. (1974) Palaeoecology of South African Australopithecines: Taung revisited, Current Anthropology 15:367-382.

------ (1984*a*) "Archaeology and Quaternary environments in the interior of southern Africa", in R. Klein (ed) Southern African prehistory and palaeoenvironments, A.A. Balkema, Rotterdam, pp1-64.

------ (1984*b*) "Late Quaternary environments in South Africa", in J.C.Vogel (ed) Late Cainozoic palaeoclimates of the southern hemisphere, A.A. Balkema, Rotterdam, pp235-265.

Butzer K.W., Stuckenrath R., Bruzewicz A.J. and Helgren D.M. (1978) Late Cainozoic palaeoclimates of the Gaap Escarpment, Kalahari margin, South Africa, Quaternary Research 10:310-339.

Cahen L. and Lepersonne J. (1952) Equivalence enter le système du Kalahari du Congo Belge et les Kalahari Beds d'Afrique australe, Mémoires du Societé Belge Géologie, Paléontologie et Hydrologie 8:1-64.

Campbell A.C and Child G. (1971) The impact of man on the environment of Botswana, Botswana Notes and Records 3:91-109.

Campbell I.A. (1989) "Badlands and badland gullying" in D.S.G. Thomas (ed) Arid Zone Geomorphology, Belhaven, London. pp.159-183.

Carlisle D. (1983) "Concentration of uranium and vanadium in calcretes and gypcretes", in R.C.L. Wilson (ed), Residual deposits, Geological Society of London Special Publication 11:185-195.

Carlisle D., Merifield P., Orme A.R and Kolke O. (1978) The distribution of calcretes and gypcretes in the southwestern United States, Based on a study of deposits in Western Australia and South West Africa, U.S. Department of Energy Report GJBX-29 (78), subcontract 76-022-E, Grand Junction, Colorado, 274pp.

Carr M.H. (1980) Survey of Martian fluvial features, NASA Technical Memo TM 81776:265-267.

Chadwick O.A., Hendricks D.M. and Nettleton W.D. (1987*a*) Silica in duric soils: I. a depositional model, Soil Science Society of America Journal 51:975-982.

------ (1987*b*) Silica in duric soils: II. Mineralogy, Soil Science Society of America Journal 51:982-985.

Chapman J. (1886) Travels in the interior of South Africa (2 Volumes), Bell and Daldy, London (Reprinted by A.A. Balkema, Cape Town, 1971).

Ciccacci S., Fredi P., Lupia Palmieri E. and Salvini F. (1987) "An approach to the quantitative analysis of the relations between drainage pattern and fracture trend", in V. Gardiner (ed) International Geomorphology 1986 Part Two, John Wiley, Chichester. pp.49-68.

Clement A.J. (1967) The Kalahari and its lost city, Longman, Cape Town.

Coates D.R. (1990) "Groundwater controls of geomorphic hydrology" in C.G. Higgins and D.R. Coates (eds) Groundwater geomorphology: the role of subsurface water in earth-surface processes and landforms, Geological Society of America Special Paper 252, Boulder, Colorado. pp341-356.

Coates J.N.M., Davies J., Gould D., Hutchins D.G., Jones C.R., Key R.M., Massey N.W.D., Reeves C.V., (1979) The Kalatraverse report one, Geological Survey of Botswana Bulletin 21, Gaborone. 402pp.

Cooke H.J. (1975) The palaeoclimatic significance of caves and adjacent landforms in western Ngamiland, Botswana, Geographical Journal 141:430-444.

------ (1977) "The palaeogeography of the middle Kalahari of northern Botswana and adjacent areas", in The Okavango delta - an international symposium, the Botswana Society, Gaborone.

------ (1979*a*) The origin of the Makgadikgadi pans, Botswana Notes and Records 11:37-42.

------ (1979*b*) K.Heine: radiocarbon chronology of late Quaternary lakes in the Kalahari, southern Africa; a discussion, Catena 6:107.

------ (1979*c*) "Botswana's present climate and the evidence for past change", in M.T. Hinchey (ed) Proceedings of the symposium on drought in Botswana, Botswana Society, Gaborone, pp 53-58.

------ (1980) Landform evolution in the context of climatic change and neotectonism in the middle Kalahari of north-central Botswana, Transactions of the Institute of British Geographers (NS) 5:80-99.

------ (1984) "The evidence from northern Botswana of late Quaternary climatic change", in J.C.Vogel (ed) Late Cainozoic palaeoclimates of the southern hemisphere, A.A. Balkema, Rotterdam, pp265-278.

Cooke H.J and Baillieul T. (1974) The caves of Ngamiland: an interim report on explorations and fieldwork 1972-74, Botswana Notes and Records 6:147-156.

Cooke H.J. and Verstappen H.Th. (1984) Landforms of the western Makgadikgadi basin in northern Botswana, with a consideration of the chronology of the evolution of lake Palaeo-Makgadikgadi, Zeitschrift für Geomorphologie 28:80-99.

Cooke R.U. and Warren A. (1973) Geomorphology in deserts, Batsford, London 390pp.

Coque R. (1962) La Tunisie pré-Saharienne, étude géomorphologique, Colin, Paris.

Cornwallis-Harris W. (1852) The wild sports of southern Africa: being the narrative of a hunting expedition from the Cape of Good Hope, through the territories of the Chief Moselekatse, to the Tropic of Capricorn, Henry G. Bohn, London, 359pp. Reprinted 1987, C. Struik (pty) Ltd, Cape Town.

Crockett R.N. and Jennings C.M.H. (1962) Note on the fieldwork carried out in the Okwa valley during January 1962, Bechuanaland Geological Survey Unpublished report RNC/6/62, Lobatse. 1pp.

------ (1964) Geology of part of the Okwa valley, Western Bechuanaland, in the vicinity of longitude 22°E, Bechuanaland Geological Survey Unpublished report RNC/17/64, Lobatse. 14pp.

------ (1965) Geology of part of the Okwa valley, western Bechuanaland, Records of the Geological Survey of Bechuanaland 1961-62, Bechuanaland Geological Survey, Gaborone. pp101-113.

Cumming R.G. (1850) Five years of a hunter's life in the far interior of South Africa, John Murray, London.

Dardis G.F., Beckedahl H.R. and Stone A.W. (1988) "Fluvial systems", in B.Moon and G. Dardis, The geomorphology of southern Africa, Southern Publishers, Johannesburg, pp30-56.

Davis W.M. (1899) The geographical cycle, Geographical Journal 14:481-504.

Deacon J. and Lancaster N. (1988) Late Quaternary palaeoenvironments of southern Africa, Clarendon Press, Oxford, 225pp.

Deacon J., Lancaster N, and Scott L. (1984) "Evidence for late Quaternary climatic change in southern Africa: summary of the proceedings of the SASQUA workshop, Johannesburg, 1983", in J.C. Vogel (ed) Late Cainozoic palaeoclimates of the southern Hemisphere, A.A. Balkema, Rotterdam, pp391-404.

De Beers Prospecting Botswana (pty) Ltd (1988) Final report for prospecting licence 21/86 and first relinquishment report for prospecting licences 19/86 and 20/86, Botswana Department of Geological Survey Unpublished Report CR1/2/72, Lobatse. 7pp.

Debenham F. (1948) Report on the water resources of Bechuanaland, N. Rhodesia, Tanganyika, Uganda and Kenya, Colonial Research Publication no 2, London pp31-39.

------ (1952) The Kalahari today, Geographical Journal 118:12-23.

De Brulyn H. (1974) Pans in the western Orange Free State, Annals of the Geological Survey of South Africa 9(2):121-124.

De Heinzelin J. (1963) "A tentative palaeogeographic map of Neogene Africa", in F.C. Howell and F. Boulicre (eds), African ecology and human evolution, Viking Publications in Anthropology, Aldine, Chicago pp648-654.

De Swardt A.M.J. and Bennet G. (1974) Structural and physiographic evolution of Natal since the Late Jurassic, Transactions of the Geological Society of South Africa 77:309-322.

De Villiers J. and Simpson E.W.S. (1974) Late Precambrian tectonic patterns in south-western Africa, Bulletin of the Precambrian Research Unit, University of Cape Town 15:141-152.

De Vries J.J. (1974) Groundwater flow systems and stream nets in the Netherlands, Editions Rodopi, Amsterdam.

------ (1976) The groundwater outcrop-erosion model: evolution of the stream network in the Netherlands, Journal of Hydrology 29:43-50.

------ (1984) Holocene depletion and active recharge of the Kalahari groundwaters - a review and an indicative model, Journal of Hydrology 70:221-232.

------ (1985) "Recharge and depletion of Kalahari groundwaters: an indicative model", in D.G. Hutchins and A.P. Lynam (eds) The proceedings of a seminar on the mineral exploration of the Kalahari, October 1983, Botswana Department of Geological Survey Bulletin 29, Gaborone. pp251-260.

De Vries J.J. and Von Hoyer M. (1988) "Groundwater recharge studies in semi-arid Botswana - a review", in I. Simmers (ed), Estimation of Natural Groundwater recharge, NATO ASI Series C 222:339-347, Reidel, Dordrecht.

Dietvorst E.J.L., De Vries J.J. and Gieske A. (1991) Coincidence of wellfields and tectonic basins in the Precambrian shield area of southeast Botswana, Ground Water 29:869-877.

Dingle R.V. and Hendey Q.B. (1984) Mesozoic and Tertiary sediment supply to the western Cape Basin (S.E. Atlantic) and palaeodrainage systems in south-western Africa, Marine Geology 56:13-26.

Dingle R.V., Siesser W.G. and Newton A.R. (1983) Mesozoic and Tertiary geology of southern Africa, A.A. Balkema, Rotterdam, 375pp.

Dixey F.H. (1950) "Part 1. Geology" in J.D. Clark (ed) The Stone Age cultures of Northern Rhodesia, South African Archaeological Society. pp9-29.

------ (1958*a*) Erosion surfaces of Africa: some considerations of age and origin, Transactions of the Geological Society of South Africa 58:265-280.

------ (1958*b*) Some aspects of the geomorphology of central and southern Africa: Alex du Toit memorial lecture No. 4 Transactions of the Geological Society of South Africa 58 annexure 58pp.

Dunne T. (1980) Function and control of channel networks, Progress in Physical Geography 4:211-239.

Dury G.M. (1968) "An introduction to the geomorphology of Australia", in G.M. Dury and M.I. Logan (eds) Studies in Australian Geography, Heinemann Education, Melbourne, pp1-36.

Du Toit A.L. (1926*a*) Report on the Kalahari reconnaissance of 1925, Department of Irrigation, Union of South Africa, Pretoria, 69pp + plates.

------ (1926*b*) The Mier Country, South African Geographical Journal 9:21-26.

------ (1927) The Kalahari and some of its problems, South African Journal of Science 24:88-101.

------ (1933) Crustal movement as a factor in the geographical evolution of South Africa, South African Geographical Journal 16:3-20.

------ (1954) The geology of South Africa (3rd edition), Oliver and Boyd, Edinburgh.

Ebert J. and Hitchcock R.K. (1978) Ancient lake Makgadikgadi, Botswana: mapping, measurement and palaeoclimatic significance, Palaeoecology of Africa 10/11:47-56.

Egyed L. (1957) The role of tectonics and morphology in the development of drainage pattern, Beitrage zur Geophysik 66:271-273.

El-Baz F., Breed C.S., Crolier M.J. and McCauley J.F. (1979) Aeolian features in the western desert of Egypt and some implications for Mars, Journal of Geophysical Research 84 n.b14:8205-8221.

El-Baz F., Boulos L., Breed C., Dardir A., Dowidar H., El-Etr H., Embabi N., Grolier M., Haynes V., Ibrahim M., Issawi B., Maxwell T., McCauley J., McHugh W., Moustafa A. and Yousif M. (1980) Journey to the Gilf Kebir and Uweinat, southwest Egypt, Geographical Journal 146:51-93.

Farr J., Cheney C., Baron J. and Peart R. (1981) GS10 Project: evaluation of underground water resources, Botswana Department of Geological Survey Final Report, Gaborone. 292pp.

Farr J., Peart R., Nelisse C. and Butterworth J. (1982) Two Kalahari pans: a study of their morphometry and evolution, Botswana Department of Geological Survey, Unpublished Report GS10/10, Lobatse.

Flach K.W., Nettleton W.D., Gile L.H. and Cady J.G. (1969) Pedocementation: induration by silica, carbonates and sesquioxides in the Quaternary, Soil Science 107(6):442-453.

Flint R.F. and Bond G. (1968) Pleistocene sand ridges and pans in western Rhodesia, Bulletin of the Geological Society of America 79:299-314.

Foster S.S.D. (1978) The likelihood of active groundwater recharge in the Botswana Kalahari, Botswana Department of Geological Survey Unpublished Report GS 10/6, Lobatse.

Foster S.S.D., Bath A.H., Farr J.L. and Lewis W.J.(1982) The likelihood of active groundwater recharge in the Botswana Kalahari, Journal of Hydrology 55:113-136.

Frankel J.J. and Kent L.E. (1938) Grahamstown surface quartzites (silcretes), Transactions of the Geological Society of South Africa 15:1-42.

Frostick L.E. and Reid I. (1979) "Drainage-net control of sediment parameters in sand-bed ephemeral streams", in A.F. Pitty (ed) Geographical approaches to fluvial processes, Geoabstracts, Norwich. pp 173-201.

Gale I.N. (1975) Borehole siting in the Ghanzi District, Botswana Department of Geological Survey Unpublished Report ING/2/75, Lobatse. 2pp.

Gale S.J. (1992) Long term landscape evolution in Australia, Earth Surface Processes and Landforms 17:323-343.

Gardiner V. (1983) "Drainage networks and palaeohydrology", in K.J. Gregory (ed) Background to palaeohydrology, John Wiley, Chichester. pp. 257-277.

Garrels R.M. and Christ C.L. (1965) Solutions, minerals and equilibria, Harper and Row, New York. 450pp.

Gieske A. and Selaola E. (1988) "A proposed study of recharge processes in fractured aquifers of semi-arid Botswana", in I. Simmers (ed) Estimation of natural groundwater recharge, NATO ISI Series C Volume 222, Reidel, Dordrecht, pp117-124.

Glassford D.K. and Semeniuk V. (1991) Arid-zone landforms and Cainozoic regolith of the Yilgarn Block of Western Australia, Excursion guidebook for the post-conference excursion on desert landscapes, October 1991, Perth, Western Australia. International Geological Correlation Programme 252, Past and Future Evolution of Deserts, 35pp.

Glennie K.W. (1970) Desert Sedimentary Environments, Elsevier, Amsterdam, 222pp.

Gomez B. and Mullen V.T. (1992) An experimental study of sapped drainage network development, Earth Surface Processes and Landforms 17:465-476.

Goodchild M.F. (1986) Spatial autocorrelation, Catmog 47, Geo Books, Norwich, 56pp.

Goudie A.S. (1969) Statistical laws and dune ridges in southern Africa, Geographical Journal 135:404-406.

------ (1970) Notes on some major dune types in southern Africa, South African Geographical Journal 52:93-101.

------ (1972*a*) The chemistry of world calcrete deposits, Journal of Geology 80:449-463.

------ (1972*b*) Climate, weathering, crust formation, dunes and fluvial features of the Central Namib Desert, near Gobabeb, South West Africa, Madoqua 1:15-31.

------ (1973*a*) Duricrusts in tropical and subtropical landscapes, Clarendon Press, Oxford, 174pp.

------ (1973*b*) The geomorphic and resource significance of calcrete, Progress in Physical Geography 5:77-118.

------ (1978) Dust storms and their geomorphological implications, Journal of Arid Environments 1:291-310.

------ (1983) "Calcrete", in A.S. Goudie and K. Pye (eds) Chemical sediments and geomorphology, Academic Press, London, pp93-132.

------ (1986*a*) The encyclopaedic dictionary of physical geography, Blackwell, Oxford, 528pp.

------ (1986*b*) Laboratory simulation of "the Wick effect" in salt weathering of rock, Earth Surface Processes and Landforms 11:275-287.

Goudie A.S. and Pye K. (1983) Chemical sediments and geomorphology, Academic Press, London, 493pp.

Goudie A.S. and Thomas D.S.G. (1985) Pans in southern Africa with particular reference to South Africa and Zimbabwe, Zeitschrift für Geomorphologie 29:1-19.

------ (1986) Lunette dunes in southern Africa, Journal of Arid Environments 10:1-12.

Gould D. and Rathbone P.A. (1985) "The geological structure of the Molopo Farms Project area" in D.G. Hutchins and A.P. Lynam (eds) The proceedings of a seminar on the mineral exploration of the Kalahari, October 1983, Botswana Department of Geological Survey Bulletin 22, Gaborone. pp160-186.

Gould D., Rathbone P.A. and Kimbell G.S. (1987) The geology of the Molopo Farms Complex, southern Botswana; Volume 1 - Text, Botswana Department of Geological Survey Bulletin 23, Gaborone. 178pp.

Gould D., Rathbone P.A. and Kimbell G.S. (1989) The geology of the Molopo Farms Complex, southern Botswana; Volume 2 - Appendices, Botswana Department of Geological Survey Bulletin 23, Gaborone. 245pp.

Graf W.L. (1983) Flood-related channel change in an arid-region river, Earth Surface Processes and Landforms 8:125-139.

------ (1988) Fluvial processes in dryland rivers, Springer-Verlag, 346pp.

Green D. (1966) The Karroo system in Bechuanaland, Bulletin of the Geological Society of Bechuanaland no.2, Gaborone. 74pp.

Greenwood P.G. and Carruthers R.M. (1973) Geophysical surveys in the Okavango delta, Report no.15, I.G.S. Geophysical Division, London, 23pp (unpublished).

Gregory K.J. (1983) (ed) Background to palaeohydrology, John Wiley, Chichester. 486pp.

Grey D.R.C. and Cooke H.J. (1977) Some problems in the Quaternary evolution of the landforms of northern Botswana, Catena 4:123-133.

Grobler N.J., Behounek N.J. and Loock J.C. (1987) Development of pans in palaeodrainage in north-western Orange Free State, Palaeoecology of Africa 19:87-96.

Grove A.T. (1969) Landforms and climatic change in the Kalahari and Ngamiland, Geographical Journal 135:191-212.

Gwosdz W. (1981) Report on a geological reconnaissance for calcrete deposits in the area of the Barolong Farms (Southern District) and near Letlhakeng (Kweneng District), Botswana Department of Geological Survey Unpublished report WG/26/81, Lobatse. 8pp.

------ (1982) Report on a calcrete deposit southeast of Letlhakeng, Kweneng District, Botswana Department of Geological Survey Unpublished report WG/38/82, Lobatse.

Gwosdz W. and Modisi M.P. (1983) The carbonate resources of Botswana, Botswana Department of Geological Survey Mineral Resources Report 6, Lobatse. 166pp.

Hagedorn J. (1988) Silcretes in the western Little Karoo and their relation to geomorphology and palaeoecology, Palaeoecology of Africa 19:371-375.

Haining R (1990) Spatial data analysis in the social and environmental sciences, Cambridge University Press, 409pp.

Harvey A.M. (1989) "The occurrence and role of arid zone alluvial fans", in D.S.G. Thomas (ed) Arid Zone Geomorphology, Belhaven, London. pp.136-158.

Heald M.T. and Larese R.E. (1974) Influence of coatings on quartz cementation, Journal of Sedimentary Petrology 44:1269-1274.

Heaton T.H.E., Talma A.S. and Vogel J.C. (1983) Origin and history of nitrate in confined groundwater in the western Kalahari, Journal of Hydrology 62:243-262.

Hegenberger W. (1982) The regional geology of northeast South West Africa/Namibia, South West Africa/Namibia Department of Geological Survey Open File report RG6, Windhoek. 22pp.

------ (1985/86, 1986/87) Stand der geologischen Kenntnisse uber das Kavangogebiet, South West Africa Scientific Society Journal XL/XLI, Windhoek, South West Africa/Namibia, pp97-113.

Hegenberger W. and Seeger K.G.(1980) The geology of the Gobabis area: explanation of Sheet 2218, South West Africa/Namibia Department of Geological Survey, Windhoek. 11pp.

Heine K. (1978*a*) Radio carbon chronology of the late Quaternary lakes in the Kalahari, Catena 5:145-149.

------ (1978*b*) Jungquarterer pluviale und interpluviale in der Kalahari (südliches Afrika), Palaeoecology of Africa 10:31-39.

------ (1979) Reply to Cooke's discussion of "K.Heine: radio carbon chronology of the late Quaternary lakes in the Kalahari", Catena 6: 259-266.

------ (1981) Aride und pluviale bedingungen wahrend der letzten kaltzeit in der südwest Kalahari (südliches Afrika), Zeitschrift für Geomorphologie, Supplementband 38:1-37.

------ (1982) The main stages of late Quaternary evolution of the Kalahari region, southern Africa, Palaeoecology of Africa 15:53-76.

------ (1987) Zum alter jungquarterer seespiegel schwankungen in der mittleren Kalahari, südliches Afrika, Palaeoecology of Africa 18:73-101.

Helgren D.M. (1978) Environmental history in the north-west Kalahari - preliminary report, Palaeoecology of Africa 10/11:65-66.

------ (1984) Historical geomorphology and geoarchaeology in the south-west Makgadikgadi basin, Botswana, Annals of the Association of American Geographers 74(2):298-307.

Helgren D.M. and Brooks A. (1983) Geoarchaeology of Gi, a Middle Stone Age site in the north-west Kalahari, Journal of Archaeological Science 10:181-187.

Herbert P. (1976) Borehole siting in the Ghanzi farms areas, Botswana Department of Geological Survey Unpublished Report PH/5/76, Lobatse. 2pp.

Hereford R. (1986) Modern alluvial history of the Paria River drainage basin, southern Utah, Quaternary Research 25:293-311.

Hesse R. (1989) Silica diagenesis: origin of inorganic and replacement cherts, Earth-Science Review 26:253-284.

Higgins C.G. (1974) Model drainage networks developed by groundwater sapping, Geological Society of America Abstracts with Programs 6:794-795.

------ (1982) Drainage systems developed by sapping on Earth and Mars, Geology 10(3):147-152.

------ (1983) Reply: drainage systems developed by sapping on Earth and Mars, Geology 11:55-56.

------ (1984) "Piping and sapping: development of landforms by groundwater outflow", in R.G. la Fleur (ed) Groundwater as a geomorphic agent, Allen and Unwin, London, pp18-58.

Hinds N.E.A. (1925) Amphitheatre valley heads, Journal of Geology 33:816-818.

Hodson A.W. (1912) Trekking the Great Thirst - sport and travel in the Kalahari Desert, T. Fisher Union Ltd, London 359pp. Reprinted 1977, Africana Book Society (pty) Ltd, Johannesburg.

Horton R.E. (1945) Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology, Bulletin of the Geological Society of America 56:275-370.

Houston J. (1973) Provisional reconnaissance hydrogeology of the southern Ghanzi District, Botswana Department of Geological Survey Unpublished Report JFTH/10/73, Lobatse. 7pp.

Howard A.D., Kochel R.C. and Holt H.E. (1988) Sapping features of the Colorado Plateau - a comparative planetary geology fieldguide, NASA Publication SP-491, 108pp.

Howard A.D. and McLane C.F. (1988) Erosion of cohesionless sediment by groundwater seepage, Water Resources Research 24(10):1659-1674.

Hutchins D.G., Hutton L.G., Hutton S.M., Jones C.R. and Loenhart E.P. (1976*a*) Geology, geomorphology and hydrology of the Okavango, Botswana Department of Geological Survey Bulletin 7, Gaborone.

Hutchins D.G., Hutton S.M. and Jones C.R. (1976*b*) "The geology of the Okavango delta", in Proceedings of the Symposium on the Okavango delta and its future utilisation (Gaborone), Botswana Society, Gaborone pp13-19.

Hutchins D.G., Peart R.J., Machacha T.P., Cornwell J.D. and Mallick D.I.J. (1979) "Reconnaissance ground geophysical survey over the Xade Complex, central Botswana", in G. McEwen (ed) The proceedings of a seminar on geophysics and the exploration of the Kalahari, Botswana Department of Geological Survey Bulletin 22, Gaborone. pp247-272.

Hutton L.G. and Lochnert E.P. (1977) Hydrochemical surveys of selected Karoo areas in Botswana, International Association of Hydrologists Congress Memoirs (Birmingham) XIII pp63-72.

Hyde L.W. (1971) "Groundwater supplies in the Kalahari area, Botswana", in Proceedings of the conference on sustained production from semi-arid areas, Botswana Society, Gaborone, pp77-87.

Jacobson G., Arakel A.V. and Chen Y.J. (1988) The central Australian groundwater discharge zone - evolution of associated calcrete and gypcrete deposits, Australian Journal of Earth Sciences 35: 549-565.

Jennings C.M.H. (1969) "Groundwater in Botswana", in Symposium on groundwater in southern Africa, Pretoria pp1-13.

------ (1974) The hydrogeology of Botswana, Unpublished Ph.D. Thesis, University of Natal, 850pp.

Jennings C.M.H. and Crockett R.N. (1961) Preliminary report on the geology of the Okwa valley west of Tswaane borehole, Bechuanaland Geological Survey Unpublished report RNC/3/61, Lobatse. 6pp.

Jennings J.N. (1979) Arnhem Land, city that never was, Geographical Magazine 51:822-827.

Johnston R.J. (1978) Multivariate statistical analysis in geography, Longman, London.

Jones C.R. (1982) The Kalahari of southern Africa, Striae 17:20-34.

Jones M.T. (1962) Report on a photogeological survey of the area between the Okavango swamps and the South West African border, Botswana Department of Geological Survey Unpublished report, Lobatse.

Jones N. (1944) The climate and cultural sequences at Sawmills, Southern Rhodesia, Occasional Papers, Rhodesia Museum 12:116-127.

Keller E.A. and Kondolf G.M. (1990) "Groundwater and fluvial processes; selected observations, with case studies by D.J. Hagerty and G.M. Kondolf" in C.G. Higgins and D.R. Coates (eds) Groundwater geomorphology: the role of subsurface water in earth-surface processes and landforms, Geological Society of America Special Paper 252, Boulder, Colorado. pp319-340.

Kelsey H.M. (1988) Formation of inner gorges, Catena 15:433-458.

Kent L.E. and Gribnitz K.-H. (1985) Freshwater shell deposits in the northeastern Cape Province: further evidence for a widespread wet phase during the late Pleistocene in southern Africa, South African Journal of Science 81:361-370.

Key R.M. (1977) The chronology of Botswana, Transactions of the Geological Society of South Africa 80:31-40.

Kimbell G.S., Burley A.J., Parker M.E., Pease S.F. and Barton K.T (1984) The gravity survey of the Molopo Farms area, southern Botswana, Botswana Department of Geological Survey Bulletin 30, Gaborone. 101pp + maps.

King L.C. (1962) The morphology of the Earth, Oliver and Boyd, Edinburgh. 699pp.

------ (1978) "The geomorphology of central and southern Africa", in M.J.A. Werger (ed) Biogeography and ecology of southern Africa, Junk Publishing, The Hague, pp1-17.

Kingston J., Woodward J.E. Malan S.P. and Jennings R.P. (1961) Geology and petroleum prospects of the Kalahari basin, Report by Mobil Oil, South Africa (pty) Ltd. unpublished.

Kirchner J. and Tredoux G. (1975) The Stampriet Artesian Basin, with specific reference to the Salt Block: the chemical composition of the groundwater with respect to geological formation, South West Africa Department of Geological Survey, Windhock. Unpublished Report.

Kirkby M.J. and Morgan R.P.C. (1980) Soil erosion, John Wiley, Chichester.

Klein R.G. (ed) (1984) Southern African Prehistory and Palaeoenvironments, A.A. Balkema, Rotterdam, 404pp.

Klein R.G., Cruz-Uribe K. and Beaumont P.B. (1991) Environmental, ecological and palaeoanthropological implications of late Pleistocene mammalian fauna from Equus Cave, Northern Cape Province, Quaternary Research 36:94-119.

Knighton D. (1984) Fluvial forms and processes, Edward Arnold, London. 218pp.

Knox J.C. (1972) Valley alluviation in south-western Wisconsin, Annals of the Association of American Geographers 67:323-342.

Kochel R.C., Howard A.D. and McLane C. (1985) "Channel networks developed by groundwater sapping in fine-grained sediments: analogs to some Martian valleys" in M.J. Woldenberg (ed) Models in Geomorphology, Allen and Unwin, London. pp 313-341.

Kochel R.C. and Piper J.F. (1986) Morphology of large valleys on Hawaii: evidence for groundwater sapping and comparisons with Martian valleys, Journal of Geophysical Research 91(b13):e175-e192.

Kogbe C.A. (1980) "The Trans-Saharan Seaway during the Cretaceous", in M.J Salem and M.T. Busrewil (eds), The geology of Libya Volume 1, Academic Press, London, pp91-95.

Kokot D.F. (1948) An investigation into the evidence bearing on recent climatic changes over southern Africa, Irrigation Department, Union of South Africa, Pretoria.

La Fleur R.G. (ed) (1984) Groundwater as a geomorphic agent, Allen and Unwin, London, 390pp.

Laity J.E. (1983) Diagenetic controls on groundwater sapping and valley formation, Colorado Plateau, as revealed by optical and electron microscopy, Physical Geography 4:103-125.

Laity J.E. and Malin M.C. (1985) Sapping processes and the development of theater-headed valley networks in the Colorado Plateau, Geological Society of America Bulletin 96:203-217.

Laity J.E., Pieri D.C. and Malin M.C. (1980) Sapping processes in tributary valley systems, NASA Technical Memo TM 81776:295-297.

Lamplugh G.W. (1902) Calcrete, Geological Magazine 9:75.

------ (1907) Geology of the Zambezi basin around the Batoka Gorge, Quarterly Journal of the Geological Society 63:162-216.

Lancaster I.N. (1977) Pleistocene lacustrine stromatolites from Urwi pan, Botswana, Transactions of the Geological Society of South Africa 80:283-285.

------ (1978*a*) The pans of the southern Kalahari, Botswana, Geographical Journal 144:81-98.

------ (1978*b*) Composition and formation of southern Kalahari pan margin dunes, Zeitschrift für Geomorphologie 22(2):148-169.

------ (1979*a*) Quaternary environments in the arid zone of southern Africa, Environmental studies paper 22, Department of Geography and Environmental Studies, University of the Witwatersrand, S. Africa.

Lancaster N. (1979*b*) Evidence for a widespread late Pleistocene humid period in the Kalahari, Nature 279:145-146.

------ (1980) Dune systems and palaeoenvironments in southern Africa, Palaeontologia Africana 23:185-189.

------ (1981) Palaeoenvironmental implications of fixed dune systems in southern Africa, Palaeogeography, Palaeoclimatology and Palaeoecology 33:327-346.

------ (1984) "Aridity in southern Africa: age, origins and expression in landforms and sediments", in J.C. Vogel (ed) Late Cainozoic palaeoclimates of the southern hemisphere, A.A. Balkema, Rotterdam, pp433-444.

------ (1986*a*) Grain size characteristics of linear dunes in the southwestern Kalahari, Journal of Sedimentary Petrology 56:395-400.

------ (1986*b*) Pans in the southwestern Kalahari: a preliminary report, Palaeoecology of Africa 17:59-68.

------ (1988) Development of linear dunes in the southwestern Kalahari, southern Africa, Journal of Arid Environments 14:233-244.

------ (1989) Late Quaternary palaeoenvironments in the southwestern Kalahari, Palaeogeography, Palaeoclimatology and Palaeoecology 70:367-376.

Langford-Smith T. (1978) (ed) Silcrete in Australia, University of New England, Armidale. 304pp.

Lawrance C.J. and Toole T. (1984) The location, selection and use of calcrete for bituminous road construction in Botswana, Transport and Road Research Laboratory Report 1122, Department of Transport, 53pp.

Lee R.B. (1979) The !Kung San: men, women and work in a foraging society, Cambridge University Press, 526pp.

------ (1984) The Dobe !Kung, Holt, Rinehart and Winston/CBS College Publishing, New York, 173pp.

Leistner O.A. (1967) The plant ecology of the southern Kalahari, Botanical Research Institute Botanical Memoir 38, Republic of South Africa Department of Agricultural Technical Services, Pretoria, 172pp.

Levin M., Hambleton-Jones B.B. and Smit M.C.B. (1985) "Uranium in the groundwater of the Kalahari regions south of the Molopo River", in D.G. Hutchins and A.P. Lynam (eds) The proceedings of a seminar on the mineral exploration of the Kalahari, October 1983, Botswana Department of Geological Survey Bulletin 29, Gaborone. pp234-250.

Lewis A.D. (1936) Sand dunes of the Kalahari within the borders of the Union, South African Geographical Journal 19:23-32.

Lister L.A. (1979) The geomorphic evolution of Zimbabwe-Rhodesia, Transactions of the Geological Society of South Africa 82(3):363-370.

Lister M.H. (1949) The journals of Andrew Geddes Bain, the Van Riebeck Society, Cape Town.

Litherland M. (1982) The geology of the area around Mamuno and Kalkfontein, Ghanzi District, Botswana, Botswana Department of Geological Survey District Memoir 4, Gaborone. 145pp.

Livingstone D. (1858) Missionary Travels and researches in South Africa, Harper and Brothers, New York, 732pp. Reprinted 1971, Johnson Reprint Corporation, New York.

Loughnan F.C. (1969) Chemical weathering of the silicate minerals, American Elsevier, New York, 154pp.

Lowe J.J. and Walker M.J.C. (1984) Reconstructing Quaternary environments, Longman, London. 389pp.

Lüdtke G. (1986) Geophysical, geochemical and geological investigations in the Ngami and Kheis areas of Botswana, 1980-1983, Final Report, Botswana Department of Geological Survey Bulletin 32, Gaborone. 319pp + maps + appendices.

Mabbutt J.A. (1955) Erosion surfaces in little Namaqualand and the ages of surface deposits in the south-western Kalahari, Transactions of the Geological Society of South Africa 58:13-29.

------ (1957) "Physiographic evidence for the age of the Kalahari sands of the Kalahari", in J.D. Clark (ed) 3rd Pan-African congress on Pre-History, Livingstone, 1955, Chatto and Windus, London, pp123-126.

------ (1977) Desert Landforms, ANU Press, Canberra.

------ (1988) "Land-surface evolution at the continental time-scale: an example from interior western Australia", in J. Firman (ed) Landscapes of the southern hemisphere, Earth-Science Review 25:457-466.

McBride E.F. (1989) Quartz cement in sandstones: a review, Earth-Science Review 26:69-112.

McCarthy T.S. (1983) Evidence for the former existence of a major southerly flowing river in Griqualand West, Transactions of the Geological Society of South Africa 86:37-49.

McCarthy T.S., Ellery W.N., Rogers K.H., Cairncross B. and Ellery K. (1986) The roles of sedimentation and plant growth in changing flow patterns in the Okavango Delta, Botswana, South African Journal of Science 82:579-584.

McCarthy T.S., Stanistreet I.G., Cairncross B., Ellery W.N., Ellery K., Oelofse R. and Grobicki T.S.A. (1988*a*) Incremental aggradation on the Okavango Delta-Fan, Botswana, Geomorphology 1: 267-278.

McCarthy T.S., Rogers K.H., Stanistreet I.G., Ellery W.N., Cairncross B. and Ellery K. (1988*b*) Features of channel margins in the Okavango Delta, Palaeoecology of Africa 19:3-14.

McCauley J.F., Schaber G.G., Breed C.S., Grolier M.J., Haynes C.V., Issawi B., Elachi C. and Blom R. (1982) Subsurface valleys and geoarchaeology of the Eastern Sahara revealed by Shuttle Radar, Science 218:1004-1020.

McCauley J.F., Breed C.S., Schaber G.G., McHugh W.P., Issawi B., Haynes C.V., Grolier M.J. and El Kilani A. (1986*a*) Palaeodrainages of the Eastern Sahara - the Radar Rivers revisited (SIR-A/SIR-B implications for a mid-Tertiary trans-African drainage system), IEEE Transactions on Geoscience and Remote Sensing Volume GE-24 Number 4:624-648.

McCauley J.F., Breed C.S. and Schaber G.G. (1986*b*) "The megageomorphology of the Radar Rivers of the Eastern Sahara", Report N 87-17139 in The Second Spaceborne Imaging Symposium, April 28-30 1986, Jet Propulsion Laboratory, Pasadena, NASA JPL Publication 86-26. pp25-35.

McConnell R.B. (1956) Notes on the geology and geomorphology of the Bechuanaland Protectorate, 20th International Geological Congress, Mexico City, 1956, Asociación de Servicios Geológicos Africanos pp175-186.

McDaid J.A. (1985) South West Africa Coal Project Vol 1, CDM (Pty) Ltd, South West Africa Department of Geological Survey/Mineral Surveys Open File report 13/175/581/84/055, Windhoek.

McEwen G. (1979) The proceedings of a seminar on geophysics and the exploration of the Kalahari, Botswana Department of Geological Survey Bulletin 22, Gaborone. 423pp.

McFarlane M.J. (1983) "Laterite", in A.S. Goudie and K. Pye (eds) Chemical sediments in geomorphology, Academic Press, London, pp7-58.

------ (1989) Dambos - their characteristics and geomorphological evolution in parts of Malawi and Zimbabwe, with particular reference to their role in the hydrogeological regime of surviving areas of African surface, Proceedings of the Groundwater Exploration and Development in Crystalline Basement Aquifers Workshop, Harare, Zimbabwe, 15-24 June 1987, Commonwealth Science Council 1 (Session 3):254-308.

------ (1990) A review of the development of tropical weathering profiles with particular reference to leaching history and with examples from Malawi and Zimbabwe, Proceedings of the Groundwater Exploration and Development in Crystalline Basement Aquifers Workshop, Harare, Zimbabwe, 15-24 June 1987, Commonwealth Science Council 1 (Session 8):93-145.

MacGregor A.M. (1916) The Karroo rocks and later sediments north west of Bulawayo, Transactions of the Geological Society of South Africa 19:14-32.

------ (1930) The Great Makarikari, Mining and Industrial Magazine, Johannesburg 2:127-129.

------ (1931) Geological notes on a circuit of the great Makarikari salt pan, Bechuanaland Protectorate, Transactions of the Geological Society of South Africa 33:89-102.

Mäckel R. (1974) Dambos: a study in morphodynamic activity on the plateau regions of Zambia, Catena 1:327-365.

Main M. (1987) Kalahari: life's variety in dune and delta, Southern Book Publishers, Johannesburg, 265pp.

Mallick D.I.J., Habgood F. and Skinner A.C. (1981) A geological interpretation of Landsat imagery and air photography of Botswana, Institute of Geological Sciences, Overseas Geology and Mineral Resources 56, London, H.M.S.O., 36pp.

Mann A.W. and Horwitz R. (1979) Groundwater calcrete deposits in Australia: some observations from Western Australia, Journal of the Geological Society of Australia 26:293-303.

Marker M.E. (1976) Note on some South African pseudo-karst, Bolotin de la Sociedad Venezolana de Espeliologia 7(13):5-12.

------ (1977) Aspects of the geomorphology of the Kuiseb river, South West Africa, Madoqua 10:199-206.

------ (1988) Tufa deposits of southern Africa: a review, Palaeoecology of Africa, 19:377-389.

Masch F.D. and Denny K.J. (1965) Grain size distribution and its effects on the permeability of unconsolidated sands, Water Resources Research Journal 2(4):665-689.

Mason R.J., Brink A.B.A. and Knight K. (1959) Pleistocene climatic significance of calcretes and ferricretes, Nature 184:568.

Masson-Smith D. and Evans R.B. (1966) Geophysical surveys in southern Bechuanaland Protectorate September 1965, Geophysical Report 36, Institute of Geological Sciences - Overseas Division.

Maufe H.B. (1920) The geological section between Bulawayo and Victoria Falls, South African Journal of Science 17:113-115.

------ (1930) Changes of climate in southern Rhodesia during late geological times, South African Geographical Journal 13:12-16.

------ (1935) Some factors in the geological evolution of Southern Rhodesia and neighbouring countries, South African Geographical Journal 18:3-21.

------ (1939) New sections in the Kalahari beds at the Victoria Falls, Rhodesia, Transactions of the Geological Society of South Africa 41:211-224.

Maxwell J.A. (1979) Field investigations of Martian canyonlands in southwestern Egypt, NASA Conference Publication 2072:54.

Mayer J.J. (1973) Morphotectonic development of the Harts River valley in realtion to the Griqualand-Transvaal axis and the Vaal and Molopo rivers, Transactions of the Geological Society of South Africa 76:183-194.

Mazor E. (1982) Rain recharge in the Kalahari - a note on some approaches to the problem, Journal of Hydrology 55:137-144.

Mazor E., Verhagen B.Th., Sellschop J.P.F., Jones M.T., Robins N.E., Hutton L. and Jennings C.M.H. (1977) Northern Kalahari groundwaters: hydrologic, isotopic and chemical studies at Orapa, Botswana, Journal of Hydrology 34:203-234.

Mazor E., Verhagen B.Th., Sellschop J.P.F., Robins S. and Hutchins L.G. (1974) Kalahari groundwaters: their hydrogen, carbon and oxygen isotopes, International Atmospheric Energy and Agriculture IAEA-SM 182/10 pp203-225.

Milnes A.R. and Thiry M. (1986) Silicification in Cainozoic sequences in arid northern South Australia (abstract), 12th International Sedimentological Congress, Canberra, Australia p213.

Mock S.J. (1976) Topological properties of some trellis pattern channel networks, United States Army Cold Regions Research and Engineering Laboratory, CRREL Report 76-46, 59pp.

Molosiwa R. (1989) Molopo: the great "river" that rarely flows, Kutlwana November 1989:10-11.

Money N.J. (1972) An outline of the geology of western Zambia, Records of the Geolgical Survey, Republic of Zambia 12, Lusaka. pp103-123.

Moore A.E. (1988) Plant distribution and the evolution of the major river systems in southern Africa, South African Journal of Geology 91(3):346-349.

Mulcahy M.J. (1967) "Landscapes, laterites and soils in south-western Australia", in J.N. Jennings and J.A. Mabbutt (eds) Landform studies from Australia and New Guinea, Cambridge University Press, pp211-230.

Nash D.J., Thomas D.S.G. and Shaw P.A. (1993) "Timescales, environmental change and valley development", in A.C. Millington and K. Pye (eds) Effects of environmental change in drylands, John Wiley, Chichester (in press).

National Parks Board (1986) Kalahari Gemsbok National Park, Unpublished brochure, National Parks Board, Pretoria, 20pp.

Netterburg F. (1969*a*) Ages of calcretes in southern Africa, South African Archaeological Bulletin 24:88-92.

------ (1969*b*) The interpretation of some basic calcrete types, South African Archaeological Bulletin 24:117-122.

------ (1975) Calcretes and silcretes at Sambio, Okavangoland, South African Archaeological Bulletin 29:83-88.

------ (1980) Geology of southern African calcretes: terminology, description, macrofeatures and classification, Transactions of the Geological Society of South Africa 83:255-283.

------ (1982) "Calcretes and their decalcification around Rundu, Okavangoland, South West Africa", Palaeoecology of Africa 15:159-169.

Nicholson S.E. and Flohn H. (1980) African environmental and climatic changes and the general atmospheric circulation in the late Pleistocene and Holocene, Climatic change 2:313-348.

Nord M. (1985) Sand rivers of Botswana: Phase II, Botswana Department of Water Affairs/SIDA, Gaborone.

Norman J.W. (1968) Photogeology of linear features in areas covered with superficial deposits, Transactions of the Institute of Mining and Metallurgy, Section B 77:60-77.

Norrish K. and Chappell B.W. (1967) "X-ray fluorescence spectrography", in J. Zussman (ed) Physical methods in determinative mineralogy, Academic Press, London, pp 161-214.

Nugent C. (1990) The Zambezi River: tectonism, climatic change and drainage evolution, Palaeogeography, Palaeoclimatology and Palaeoecology 78:55-69.

------ (1992) The Zambezi River: tectonism, climatic change and drainage evolution - reply to discussion, Palaeogeography, Palaeoclimatology and Palaeoecology 91:178-182.

Ollier C.D. (1991*a*) Aspects of silcrete formation in Australia, Zeitschrift für Geomorphologie 35:151-163.

------ (1991*b*) Laterite profiles, ferricrete and landscape evolution, Zeitschrift für Geomorphologie 35:165-173.

Osterkamp W.R. and Wood W.W. (1987) Playa lake basins on the Southern High Plains of Texas and New Mexico: Part 1. Hydrologic, geomorphic and geologic evidence for their development, Bulletin of the Geological Society of America 99:215-223.

Ovenden J.C. and Gregory K.J. (1980) The permanence of stream networks in Britain, Earth Surface Processes 5:47-60.

Owens M. and Owens D. (1984) Cry of the Kalahari, Collins, 341pp.

Partridge T.C. (1969) Fluvial features and climatic change during the Quaternary in South Africa, South African Archaeological Bulletin 24: 106-116.

------ (1985) The palaeoclimatic significance of Cainozoic terrestrial stratigraphic and tectonic evidence from southern Africa: a review, South African Journal of Science 81:245-247.

Partridge T.C. and Maud R.R. (1987) Geomorphic evolution of southern Africa since the Mesozoic, South African Journal of Geology 90(2):179-208.

------ (1988) "The geomorphic evolution of southern Africa: a comparative review", in Dardis G.F. and Moon B.P. (eds) Geomorphological studies in southern Africa, A.A. Balkema, Rotterdam, pp5-15.

Passarge S. (1899) Dr. Passarge's journeys in South Africa, Geographical Journal 14:310-313.

------ (1904) Die Kalahari, Dietrich Reimer, Berlin, 822pp.

Peabody F.E. (1954) Travertines and cave deposits of the Kaap Escarpment of South Africa and the type locality of *Australopithecus africanus*, Bulletin of the Geological Society of America 65:671-706.

Peart R.J. (1979) "Some aspects of hydrogeophysical exploration in areas overlain by Kalahari Beds", in G. McEwen (ed) The proceedings of a seminar on geophysics and the exploration of the Kalahari. Botswana Department of Geological Survey Bulletin 22, Gaborone. pp361-383.

Peel R.F. (1941) Denudational landforms of the central Libyan desert, Journal of Geomorphology 4:3-23.

------ (1966) The landscape in aridity, Transactions of the Institute of British Geographers 38:1-23.

Pickford M. and Mein P. (1988) The discovery of fossiliferous Plio-Pleistocene cave fillings in Ngamiland, Comptes rendus de l'academie des sciences Serie II - mecanique physique chemie sciences de l'univers sciences de la terre 307:1681-1686.

Pickup G. (1977) "Adjustment of stream-channel shape to hydrologic regime" in K.J. Gregory (ed) River channel changes, John Wiley, Chichester. pp.47-60.

Pickup G., Allan G., and Baker V.R. (1988) "History, palaeochannels and palaeofloods of the Finke River, Central Australia", in Warner R.F. (ed) Fluvial geomorphology of Australia, Academic Press. pp 177-200.

Pieri D.C. (1980) Martian valleys: morphology, distribution, age and origin, Science 210: 895-897.

Pieri D.C., Malin M.C. and Laity J.E. (1980) Sapping: network structure in terrestial and Martian valleys, NASA Technical Memo TM-81979:292-293.

Pike J.G. (1971*a*) Rainfall and evapotranspiration in Botswana, U.N.D.P./F.A.O. Technical Document 1, Gaborone.

------ (1971*b*) "The development of the water resources of the Okavango Delta" in Proceedings of the Conference on Sustained Production from Semi-arid areas, Botswana Notes and Records, special edition 1:35-40.

Range P. (1910) Die deutsche Sudkalahari, Ges Erdk Berlin 46:592-619.

------ (1912) Topography and geology of the German South Kalahari, Transactions of the Geological Society of South Africa 15:63-73.

------ (1914) Das artesische Becken in der Sudkalahari, Dtsch Kolonialbl 8:494-509.

Radtke U., Brückner H., Mangini A. and Hausmann R. (1988) Problems encountered with absolute dating (Uranium series, ESR) of Spanish calcretes, Quaternary Science Review 7:439-445.

Radtke U. and Brückner H. (1991) Investigation on age and genesis of silcretes in Queensland (Australia) - preliminary results, Earth Surface Processes and Landforms 16:547-554.

Rathbone P.A. and Gould D. (1982) The geology of the Molopo Farms project area, Botswana Department of Geological Survey, Unpublished Report PAR/1/82, Lobatse.

Reeves C.C. (1970) Origin, classification and geologic history of caliche, Journal of Geology 78:86-95.

Reeves C.V. (1972) Evidence of rifting in the Kalahari, Nature 237:96.

------ (1977) The delineation of crustal provinces in southern Africa, from a compilation of gravity data, Annual report of the Research Institute of African Geology, University of Leeds 1976 20:36-41.

------ (1978*a*) The gravity survey of Ngamiland 1970-71, Botswana Department of Geological Survey Bulletin 11, Gaborone. 84pp.

------ (1978*b*) A failed Gondwana spreading axis in southern Africa, Nature 273:222.

Reeves C.V. and Hutchins D.G. (1975) Crustal structures in central southern Africa, Nature 254:408-410.

Reeves C.V. and Hutchins D.G. (1976) The national gravity survey of Botswana, Botswana Department of Geological Survey Bulletin 5, Gaborone.

Reid I. and Frostick L.E. (1989) "Channel form, flows and sediments in deserts", in D.S.G. Thomas (ed) Arid Zone Geomorphology, Belhaven, London. pp 117-135.

Republic of Botswana (Ministry of Mineral Resources and Water Affairs, Department of Water Affairs)/VIAK Ab (1984*a*) Eastern Botswana regional water supply - main report, Botswana Government report 7072.891117, 271pp.

------ (1984*b*) Eastern Botswana regional water supply - Short term measures, Botswana Government report 7072.891117, 127pp.

------ (1984*c*) Eastern Botswana regional water supply - Supplementary technical reports, Botswana Government report 7072.891117.

Richards K. (1982) Rivers - form and process in alluvial channels, Methuen, London. 357pp.

Robb J.M. (1990) "Groundwater processes in the submarine environment", in C.G. Higgins and D.R. Coates (eds) Groundwater geomorphology: the role of subsurface water in earth-surface processes and landforms, Geological Society of America Special Paper 252, Boulder, Colorado. pp267-281.

Robb J.M., O'Leary D.W., Booth J.S. and Kohout F.A. (1982) Submarine spring sapping as a geomorphic agent on the East Coast Continental Slope, Geological Society of America Abstracts and Programs 14:600.

Rogers A.W. (1907) Geological survey of parts of Vryburg, Kuruman, Hay and Gordonia, Twelfth Annual Report of the Geological Commission, Geological Commission of the Colony of the Cape of Good Hope, Cape Town. pp 11-122.

------ (1934) The build of the Kalahari, South African Geographical Journal 17:3-12.

------ (1936) The surface geology of the Kalahari, Transactions of the Royal Society of South Africa 24(1):57-80.

Rust B.R. and Nanson G.C. (1986) Contemporary and palaeo channel patterns and the Late Quaternary stratigraphy of Cooper Creek, southwest Queensland, Australia, Earth Surface Processes and Landforms 11:581-590.

Rust U. (1975) "Tectonic and sedimentary framework of Gondwana Basins in southern Africa", in K.S.W. Campbell (ed) Gondwana Geology, ANU Press, Canberra. pp 537-564.

Rust U., Schmidt H.H. and Dietz K.R. (1984) Palaeoenvironments of the present day arid south-western Africa 30,000 - 5,000 B.P.: results and problems, Palaeoecology of Africa 16:109-148.

(SACS) (1980) *see* South African Committee for Stratigraphy.

Schaber G.G., McCauley J.F., Breed C.S. and Olhoeft G.R (1986) Shuttle Imaging Radar: physical controls on signal penetration and sub-surface scattering in the Eastern Sahara IEEE Transactions on Geoscience and Remote Sensing Volume GE-24 Number 4:603-623.

Schick A.P. (1970) "Desert floods", Symposium on the results of research on representative and experimental basins, Int. Assoc. Sci. Hydrol., UNESCO, pp 479-493.

Schick A.P., Lekach J. and Hassan M.A. (1987) "Vertical exchange of coarse bedload in desert streams", in L.E. Frostick and I. Reid (eds) Desert sediments: ancient and modern, Geological Society of London Special Publication 35, Blackwell, Oxford. pp 7-16.

Scholz C.H. (1975) Seismicity, tectonics, and seismic hazard of the Okavango delta, U.N.D.P./F.A.O. Final Project Report BOT/71/506, Government of the Republic of Botswana, Gaborone, 40pp.

Scholz C.H., Koczynski T.A. and Hutchins D.G. (1976) Evidence for incipient rifting in southern Africa, Geophysical Journal of the Royal Astronomical Society 44:135-144.

Schulze B.R. (1972) "South Africa", in J.F. Griffiths (ed) "Climates of Africa, World Survey of Climatology, Volume 10, Elsevier, Amsterdam, pp501-586.

Schumm S.A. (1968) River adjustment to altered hydrologic regimen - Murrumbidgee River and palaeochannels, Australia, U.S. Geological Survey Professional Paper 598, 65pp.

------ (1969) River metamorphosis, Journal of Hydraulics Division, American Society of Civil Engineers 95 (HY1):255-273.

Schumm S.A. and Khan H.R. (1972) Experimental study of channel patterns, Bulletin of the Geological Society of America 83:1755-1770.

Schumm S.A. and Phillips L. (1986) Composite channels of the Canterbury Plains, New Zealand: a Martian analogue, Geology 14:326-330.

Schwarz E.H.L. (1920) The Kalahari, or Thirstland redemption, Maskew Miller, Cape Town; Blackwell, Oxford, 163pp.

Sekwale M. (1984) "Hydrological data collection, storage, retrieval and water law in Botswana", in Challenges in African Hydrology and Water Resources (Proceedings of the Harare symposium, July 1984), International Association of Hydrological Sciences Publication 144, pp221-228.

Semeniuk V. and Seale D.J. (1985) Distribution of calcrete in Holocene coastal sands in relation to climate, SW Australia, Journal of Sedimentary Petrology 55:86-95.

Sharon D. (1972) The spottiness of rainfall in a desert area, Journal of Hydrology 17:161-175.

Sharp R.P. (1973) Mars: fretted and chaotic terrains, Journal of Geophysical Research 78:4063-4072.

Sharp R.P. and Malin M.C. (1985) Channels on Mars, Geological Society of America Bulletin 86:593-609.

Shaw G. and Wheeler D. (1985) Statistical techniques in geographical analysis, John Wiley, Chichester, 364pp.

Shaw P.A. (1984) A historical note on the outflows of the Okavango Delta system, Botswana Notes and Records 16:127-130.

------ (1985*a*) Late Quaternary landforms and environmental change in north-west Botswana: the evidence of lake Ngami and the Mababe depression, Transactions of the Institute of British Geographers 10:333-346.

------ (1985*b*) The desiccation of Lake Ngami: an historical perspective, Geographical Journal 151:318-326.

------ (1986) The palaeohydrology of the Okavango delta - some preliminary results, Palaeoecology of Africa 17:51-58.

------ (1988*a*) "Lakes and pans", in B. Moon and G. Dardis (eds) The geomorphology of southern Africa, Southern Publishers, Johannesburg pp120-140 .

------ (1988*b*) "After the flood: the fluvio-lacustrine landforms of northern Botswana", in J. Firman (ed) Landscapes of the southern hemisphere, Earth-Science Review 25:449-456.

------ (1989) "Fluvial systems of the Kalahari: a review", in A. Yair and S. Berkowicz (eds), Arid and semi-arid environments - geomorphological and pedological aspects, Catena Supplement 14:119-126.

Shaw P.A. and Cooke H.J. (1986) Geomorphic evidence for the late Quaternary palaeoclimates of the middle Kalahari of northern Botswana, Catena 13:349-359.

Shaw P.A., Cooke H.J. and Thomas D.S.G. (1988) Recent advances in the study of Quaternary landforms in Botswana, Palaeoecology of Africa 19:15-26.

Shaw P.A., Cooke H.J. and Perry C.C (1991) Microbialitic silcretes in highly alkaline environments: some observations from Sua Pan, Botswana, South African Journal of Geology 93:803-808.

Shaw P.A. and De Vries J.J. (1988) Duricrust, groundwater and valley development in the Kalahari of south-east Botswana, Journal of Arid Environments 14(3):245-254.

Shaw P.A. and Thomas D.S.G. (1988) Lake Caprivi: a late Quaternary link between the Zambezi and middle Kalahari drainage systems, Zeitschrift für Geomorphologie 32(3):329-337.

------ (1989) "Playas, Lakes and Pans", in D.S.G. Thomas (ed) Arid Zone Geomorphology, Belhaven/Halstead, London, pp184-205.

------ (1992) "Geomorphological processes, environmental change and landscape sensitivity in the Kalahari region of southern Africa", in D.S.G. Thomas and R. Allison (eds) Landscape sensitivity, John Wiley, Chichester.

Shaw P.A., Thomas D.S.G. and Nash D.J. (1993) Late Quaternary fluvial activity in the dry valleys (*mekgacha*) of the Middle and Southern Kalahari, southern Africa, Journal of Quaternary Science (in press).

Shreve R.L. (1966) Statistical law of stream numbers, Journal of Geology 74:17-37.

Siddiqui S.H. and Parizek R.R. (1971) Hydrogeologic factors influencing well yields in folded and faulted carbonate rocks in central Pennsylvania, Water Resources Research 7:1295-1312.

Siegel S. (1956) Non-parametric statistics for the behavioral sciences, McGraw-Hill, London, 312pp.

Siesser W.G. (1973) Diagenetically formed ooids and intraclasts in South African calcretes, Sedimentology 20(4):539-551.

Siever R. (1962) Silica solubility 0°C-200°C, and the diagenesis of siliceous sediments, Journal of Geology 70:127-150.

Silberbauer G.B. (1981) Hunter and habitat in the Central Kalahari Desert, Cambridge University Press, 330pp.

Smale D. (1973) Silcretes and associated silica diagenesis in southern Africa and Australia, Journal of Sedimentary Petrology 43(4):1077-1089.

Small R.J. (1964) The escarpment dry valleys of the Wiltshire Chalk, Transactions of the Institute of British Geographers 34:33-52.

Smart J.S. (1968) Statistical properties of stream lengths, Water Resources Research 4:1001-1014.

Smit P.J. (1972) The Karoo system in the Kalahari of the Northern Cape Province, Annals of the Geological Survey of South Africa 9:79-81.

------ (1977) Die geohidrologie in die opvanggebied van die Molopovivier in die noordlike Kalahari, Unpublished D.Sc. Thesis, University of the Orange Free State, Bloemfontein.

Smith A.M. (1991) Extreme palaeofloods: their climatic significance and the chances of floods of similar magnitude recurring, South African Journal of Science 87:219-220.

------ (1992) Holocene palaeoclimatic trends from palaeoflood analysis, Palaeogeography, Palaeoclimatology and Palaeoecology 97:235-240.

Smith R.A. (1984) Lithostratigraphy of the Karoo stratigraphy in Botswana, Botswana Department of Geological Survey Bulletin 26(1), Gaborone. 260pp.

South African Committee for Stratigraphy (SACS) (1980) Stratigraphy of South Africa, Part 1. Lithostratigraphy of the Republic of South Africa, South West Africa/Namibia, and the Republics of Bophuthatswana, Transkei and Venda, Handbook of the Geological Survey of South Africa 8, Pretoria, 690pp.

Sparks B.W. and Lewis W.V. (1957-58) Escarpment dry valleys near Pegsdon, Hertfordshire, Proceedings of the Geologists Association 68:26-38.

Stear W.M. (1985) Comparison of the bedform distibution and dynamics of the modern and ancient sandy ephemeral flood deposits in the south-western Karoo region, South Africa, Sedimentary Geology 45:209-230.

Stengel H.W. (1964) Die Riviere der Namib und ihr zulauf zum Atlantik "I Teil: Kuiseb and Swakop", Scientific Paper of the Namib Desert Research Station , Original Print 22, 50pp.

------ (1966) Die Riviere der Namib und ihr zulauf zum Atlantik "II Teil: Omaruru and Ugab", Scientific Paper of the Namib Desert Research Station, Original Print 30, 35pp.

Stephens C.G. (1971) Laterite and silcrete in Australia, Geoderma 5:5-52.

Stewart A.J., Blake D.H. and Ollier C.D. (1986) Cambrian river terraces and ridgetops in central Australia: oldest persisting landforms?, Science 233:758-761.

Stigand A.G. (1923) Ngamiland, Geographical Journal 62:401-419.

Stiller D. (1983) Comment: drainage systems developed by sapping on Earth and Mars, Geology 11:54-55.

Stow G.W. (1873) The origin of Pans, Quarterly Journal of the Geological Society of London 30:589-680.

Strahler A.N. (1952) Hypsometric (area-altitude) analysis of erosional topography, Bulletin of the Geological Society of America 63:1117-1142.

Street F.A. (1980) The relative importance of climate and local hydrogeologic factors in causing lake level fluctuations, Palaeoecology of Africa 12:137-158.

------ (1981) Tropical palaeoenvironments, Progress in Physical Geography 5:157-185.

Street F.A. and Grove A.T. (1976) Environmental and climatic implications of late Quaternary lake-level fluctuations in Africa, Nature 261:385-390.

Street-Perrott F.A. and Roberts N. (1983) "Fluctuations in closed-basin lakes as an indicator of past atmospheric circulation patterns", in F. A. Street-Perrott, M. Beran and R. Ratcliffe (eds) Variations in the global water budget Reidel, Dordrecht pp331-345.

Stuart D.M. and Dixon R.M. (1973) Water movement and caliche formation in layered arid and semi-arid soils, Proceedings of the Soil Science Society of America 37:323-324.

Summerfield M.A. (1978) The nature and origin of silcrete with particular reference to southern Africa, Unpublished D.Phil.Thesis, University of Oxford.

------ (1981) The nature and occurrence of silcrete, southern Cape Province, South Africa, School of Geography, University of Oxford, Research Paper 28. 36pp.

------ (1982) "Distribution, nature and probable genesis of silcrete in arid and semi-arid southern Africa", in D.H. Yaalon (ed) Aridic soils and geomorphic processes, Catena Supplement 1:37-65.

------ (1983*a*) Silcrete as a palaeoclimatic indicator: evidence from southern Africa, Palaeogeography, Palaeoclimatology and Palaeoecology 41: 65-79.

------ (1983*b*) "Silcrete", in A.S. Goudie and K. Pye (eds) Chemical sediments and geomorphology, Academic Press, London, pp19-91.

------ (1983*c*) Petrography and diagenesis of silcrete from the Kalahari Basin and Cape coastal zone, southern Africa, Journal of Sedimentary Petrology 53:895-909.

------ (1983*d*) "Geochemistry of weathering profile silcretes, southern Cape Province, South Africa", in R.C.L. Wilson (ed), Residual deposits, Geological Society of London Special Publication 11:167-178, London.

------ (1984) Isovolumetric weathering and silcrete formation, southern Cape Province, South Africa, Earth Surface Processes and Landforms 9:135-141.

------ (1985*a*) "Plate tectonics and landscape development on the African continent", in M. Morisawa and J.T. Hack (eds) Tectonic geomorphology, Allen and Unwin, Boston, pp27-51.

------ (1985*b*) "Tectonic background to long term landform development in tropical Africa", in I. Douglas and T. Spencer (eds) Environmental change and tropical geomorphology, Allen and Unwin, London, pp281-294.

------ (1986) Reply to discussion of - silcrete as a palaeoclimatic indicator: evidence from southern Africa, Palaeogeography, Palaeoclimatology and Palaeoecology 52:356-360.

------ (1987) Neotectonics and landform genesis, Progress in Physical Geography 11:384-397.

Swanevelder C.J. (1974) 'n Morfometriese studie van die Tsauchabvallei van die sentrale Namib, South African Geographer 4:325-334.

Tanaka J. (1976) "Subsistence ecology of Central Kalahari San", in R.B. Lee and I. De Vore (eds) (1976) Kalahari hunter-gatherers: studies of the !Kung San and their neighbors, Harvard University Press, Cambridge Massachusetts, pp98-119.

Tankard A.J., Jackson M.P.A., Eriksson K.A., Hobday D.K., Hunter D.R. and Minter W.E.L. (1982) Crustal evolution of southern Africa, 38 billion years of earth history, Springer-Verlag, New York, 522pp.

Tapley I.J. (1988) "The reconstruction of palaeodrainage and regional geologic structures in Australia's Canning and Officer basins using NOAA - AVHRR satellite data", in J. Firman (ed) Landscapes of the southern hemisphere, Earth-Science Review 25:409-426.

Taylor G. and Ruxton B.P (1987) A duricrust catena in south-east Australia, Zeitschrift für Geomorphologie 31:305-410.

Temi S.C and Oni S.F. (1991) Detection of groundwater flow in fractured media through remote sensing techniques - some Nigerian cases, Journal of African Earth Sciences 12:461-466.

Terra Surveys Ltd. (1978) Reconnaissance aeromagnetic survey of Botswana 1975-77 - final interpretation report, Canadian International Development Agency and Botswana Department of Geological Survey, Final Report, Gaborone.

Thiry M. (1989) Geochemical evolution and palaeoenvironments of the Eocene continental deposits of the Paris Basin, Palaeogeography, Palaeoclimatology and Palaeoecology 70:153-163.

Thiry M. and Millot G. (1987) Mineralogical forms of silica and their sequence of formation in silcretes, Journal of Sedimentary Petrology 57:343-352.

Thiry M., Ayrault M.B. and Grisoni J. (1988) Ground-water silicification and leaching in sands: example of the Fontainebleau Sand (Oligocene) in the Paris Basin, Bulletin of the Geological Society of America 100:1283-1290.

Thomas D.S.G. (1982) Evidence of Quaternary palaeoclimates in western Zimbabwe - a preliminary assessment, Paper presented to the southern Africa conference of the Commonwealth Geographical Bureau, Lusaka, June 1982.

------ (1983/84) Geomorphic evolution and river channel orientation in north west Zimbabwe, Proceedings of the Geological Association of Zimbabwe 15:12-22.

------ (1984*a*) Ancient ergs of the former arid zones of Zimbabwe, Zambia and Angola, Transactions of the Institute of British Geographers 9:75-88.

------ (1984*b*) Late Quaternary environmental change in central southern Africa, with particular reference to extensions of the arid zone, Unpublished D.Phil Thesis, University of Oxford.

------ (1987*a*) "Discrimination of depositional environments using sedimentary characteristics, in the mega Kalahari, central southern Africa", in L. Frostick and I. Reid (eds) Desert sediments ancient and modern, Geological Society Special Publication 35, Blackwell Scientific Publications, London, pp293-306.

------ (1987*b*) Arid geomorphology, Progress in Physical Geography 11:419-431.

------ (1988*a*) Analysis of linear dune sediment-form relationships in the Kalahari dune desert, Earth Surface Processes and Landforms 13:545-553.

------ (1988*b*) The nature and depositional setting of arid and semi-arid Kalahari sediments, southern Africa, Journal of Arid Environments 14:17-26.

------ (1988*c*) "The geomorphological role of vegetation in the dune systems of the Kalahari", in Dardis G.F. and Moon B.P. (eds) Geomorphological studies in southern Africa, A.A. Balkema, Rotterdam, pp145-158.

------ (1992) Desert dune activity: concepts and significance, Journal of Arid Environments 22:31-38.

Thomas D.S.G. and Goudie A.S. (1984) "Ancient ergs of the southern hemisphere", in J.C. Vogel, Late Cainozoic palaeoclimates of the southern hemisphere, A.A. Balkema, Rotterdam, pp407-418.

Thomas D.S.G. and Martin H.E. (1987) Grain size characteristics of linear dunes in the southwestern Kalahari - discussion, Journal of Sedimentary Petrology 57:572-573.

Thomas D.S.G. and Shaw P.A. (1988) Late Cainozoic drainage evolution in the Zambezi Basin: geomorphological evidence from the Kalahari Rim, Journal of African Earth Science 7:611-618.

------ (1990) The deposition and development of the Kalahari Group sediments, central southern Africa, Journal of African Earth Sciences 10:187-197.

------ (1991*a*) The Kalahari Environment, Cambridge University Press, Cambidge, 284pp.

------ (1991b) Relict desert dunes systems: interpretations and problems, Journal of Arid Environments 20:1-14.

------ (1992) The Zambezi River: tectonism, climatic change and drainage evolution - is there really evidence for a catastrophic flood? A discussion, Palaeogeography, Palaeoclimatology and Palaeoecology 91:175-182.

Thomas D.S.G. and Tsoar H. (1990) "The geomorphological role of vegetation in desert dune systems", in J. Thornes (ed) Vegetation and erosion, John Wiley, Chichester pp471-489.

Thomas D.S.G., Nash D.J., Shaw P.A. and Van Der Post C. (1993) Present day lunette sediment cycling at Witpan in the arid southwestern Kalahari Desert, Catena (in press).

Thomas M.F. and Goudie A.S. (1985) (eds) Dambos: small channelless valleys in the tropics, Zeitschrift für Geomorphologie, Supplementband 52, 222pp.

Thomas M.F. and Summerfield M.A. (1987) "Long-term landform development: key themes and research problems", in V. Gardiner (ed) International Geomorphology 1986 Volume 2, John Wiley, Chichester. pp.935-956.

Thomas R.J., Thomas M.A. and Malherbe S.J. (1988) The geology of the Nossob and Twee Rivieren areas: explanation of sheets 2520 and 2620, Republic of South Africa Department of Mineral and Energy Affairs, Department of Geological Survey, Pretoria. 17pp.

Thoregren U. and Löfroth B. (1989) Ground probing radar technique as a method for road material investigation in Botswana: report from a pilot scale survey carried out during April and May 1988, Republic of Botswana Ministry of Works and Communications, Roads Department, Unpublished report, 42pp + 23 figs.

Timje H. (1987) Letlhakeng groundwater investigation project, Phase 2, Botswana Department of Geological Survey Unpublished report HT/1/87, Lobatse. 45pp + figs.

Tombale R.A. (1986) A brief description of the geology around Jwaneng, Botswana Department of Geological Survey Unpublished report, Lobatse. 1pp.

Torgersen T., De Deckker P., Chivas A.R. and Bowler J.M. (1986) Salt lakes: a discussion of processes influencing palaeoenvironmental interpretations and recommendations for future study, Palaeogeography, Palaeoclimatology and Palaeoecology 54:7-19.

Twidale C.R. and Hutton J.J. (1986) Silcrete as a climatic indicator: discussion, Palaeogeography, Palaeoclimatology and Palaeoecology 52:351-360.

Tyson P.D. (1979) "Southern African rainfall: past, present and future", in M.T.Hinchey (ed) Proceedings of the Symposium on Drought in Botswana, Botswana Society, Gaborone, pp45-52.

------ (1986) Climatic change and variability in southern Africa, Oxford University Press, 220pp.

Union Carbide (1977) Final report, reconnaissance permit 1/77 - report on radiometric flying programme over selected fossil drainages in the Kalahari, Botswana (by R.G. Spencer), Botswana Department of Geological Survey Unpublished report CR28/2/5, Lobatse. 7pp.

------ (1978) Final report of reconnaissance permit numbers 6/77 and 7/78, Botswana, Botswana Department of Geological Survey Unpublished report CR28/2/7, Lobatse. 11pp.

------ (1979*a*) Combined quarterly report for prospecting licences 23/78, 24/78, 25/78, 26/78, for the period 1st April to 30th June 1979, Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse. 3pp.

------ (1979*b*) Quarterly report for prospecting licences 23/78, 24/78, 25/78, 26/78, 4/79, 5/79, 6/79, 7/79, 8/79 and 9/79, September 1979 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse. 6pp.

------ (1979*c*) Botswana uranium programme, Quarterly report for prospecting licence numbers 26/78, 9/79, 4/79, 5/79, 6/79, 7/79 and 8/79, December 1979 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse. 5pp.

------ (1979*d*) Final report 23-24-25/78, Exploration for radioactive minerals in the Ghanzi area (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/2/6, Lobatse. 13pp.

------ (1980*a*) Quarterly report for prospecting licence numbers 26/78, 4/79, 5/79, 6/79, 7/79, 8/79, 9/79 and 23/79, March 1980 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse. 3pp.

------ (1980*b*) UCEX/CEGB joint venture Botswana, Quarterly report for prospecting licence numbers 26/78, 4/79, 5/79, 6/79, 7/79, 8/79, 9/79 and 23/79, June 1980 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse. 9pp.

------ (1980*c*) UCEX/CEGB joint venture in Botswana, Third quarterly report for prospecting licence numbers 4/79, 5/79, 6/79, 7/79, 8/79, 9/79, 23/79, 26/78, 3/80, 4/80 and 5/80, September 1980 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/1/4, Lobatse.

------ (1980*d*) UCEX - CEGB Botswana uranium in calcrete project, Final report on prospecting licence numbers 26/78, 23/79, 6/79, 7/79, 8/79, 9/79, 4/79, 5/79, 3/80, 4/80 and 5/80 (D.J. Jack), Botswana Department of Geological Survey Unpublished report CR28/2/9, Lobatse. 17pp + maps.

U.N.D.P./F.A.O. (1977) Investigation of the Okavango delta as a primary water resource for Botswana, AG:DP/BOT/71/506 Technical Reports 1 and 2, Gaborone.

Upton G. and Fingleton B. (1985) Spatial data analysis by example, John Wiley, Chichester. 410pp.

Urangesellschaft mbh and Co Kommanditgesellschaft (1978) Terminal report on the radioactive minerals exploration programme in the Mmamabula area, Grant 23-25/77, Botswana Department of Geological Survey Unpublished report CR33/2/1, Lobatse. 25pp.

Van De Graaff W.J.E. (1983) "Silcrete in Western Australia: geomorphological settings, textures, structures and their genetic implications", in R.C.L. Wilson (ed) Residual deposits: surface related weathering processes and materials, Blackwell Scientific, London, pp159-166.

Van De Graaff W.J.E., Crowe R.W.A., Bunting J.A. and Jackson M.J. (1977) Relict early Caenozoic drainages in arid western Australia, Zeitschrift für Geomorphologie 21:379-400.

Van Straten O.J. (1955) The geology and groundwater of the Ghanzi cattle route, Annual Report of the Geological Survey of Bechuanaland Protectorate 1955, Gaborone. pp28-39.

Van Straten O.J. (1963) A note on the groundwater potential of certain areas adjacent to the main internal drainage system of the northern Bechuanaland Protectorate, Department of Overseas Studies, Tolworth, U.K., Development Study no.1.

Van Zinderen Bakker E.M. (1976) The evolution of late Quaternary palaeoclimates of southern Africa, Palaeoecology of Africa 9:160-202.

------ (1980) Comparison of late Quaternary climatic evolutions in the Sahara and Namib-Kalahari region, Palaeoecology of Africa 12:381-399.

------ (1982) African palaeoenvironments 18,000 years B.P., Palaeoecology of Africa 15:77-99.

Van Zinderen Bakker E.M. and Coetzee J.A. (1972) A reappraisal of late Quaternary climatic evidence from tropical Africa, Palaeoecology of Africa 7:151-181.

Veatch A.C. (1935) Evolution of the Congo Basin, Memoirs of the Geological Society of America 3. 183pp.

Verhagen B.Th. (1983) Environmental isotope study of a groundwater supply project in the Kalahari of Gordonia, International Symposium on Isotope Hydrology in Water Resource Development IAEA-SM 270/50 pp415-432.

------ (1984) "Environmental isoptope hydrology in southern Africa", in Challenges in African Hydrology and Water Resources (Proceedings of the Harare symposium, July 1984), International Association of Hydrological Sciences Publication 144, pp161-174.

Verhagen B.Th., Mazor E. and Sellschop J.P.F. (1974) Radiocarbon and tritium evidence for direct rain recharge to groundwaters in the northern Kalahari, Nature 249:643-644.

Verhagen B.Th., Smith P.E., Dziembowski Z. and Oosthuizen J.H. (1978) An environmental isotope study of a major dewatering operation at Sishen Mine, northern Cape Province, IAEA-SM-228/1 pp65-81.

VIAK Ab (1983) Lineament studies in the area between Molopolole and Letlhakeng, Botswana Department of Geological Survey and Department of Water Affairs, Unpublished report, Lobatse.

Visser J.N.J. (1983) An analysis of the Permo-Carboniferous glaciation in the marine Kalahari basin, southern Africa, Palaeogeography, Palaeoclimatology and Palaeoecology 44:295-315.

Vogel J.C. (ed) (1984) Late Cainozoic palaeoclimates of the southern hemisphere, A.A. Balkema, Rotterdam, 520pp.

------ (1985) Southern Africa at 18,000 B.P., South African Journal of Science 81:250-251.

------ (1989) Evidence of past climatic change in the Namib desert, Palaeogeography, Palaeoclimatology and Palaeoecology 70:355-366.

Von Hoyer M., Keller S., and Rehder S. (1985) Core borehole Lethlakeng 1, Botswana Department of Geological Survey Unpublished report MVH/4/85, Lobatse. 7pp.

Walker I.R. (1973*a*) Towards a formalisation of the terms Kgwebe Formation and Ghanzi Formation, Botswana Department of Geological Survey Unpublished report IRW/4/73, Lobatse. 6pp.

------ (1973*b*) A stromatolite occurrence in south Ngamiland, Botswana Department of Geological Survey Unpublished report IRW/7/73, Lobatse. 4pp.

------ (1973*c*) Stratigraphic section through the Kalahari Beds at Jwaneng, Ngwaketse District, Botswana Department of Geological Survey Unpublished report IRW/9/73, Lobatse.

Walls R.A., Harris W.B. and Nunan W.E. (1975) Calcareous crust (caliche) profiles, and early subaerial exposure of Carboniferous carbonates, north-eastern Kentucky, Sedimentology 22:417-440.

Watson A. (1989) "Desert crusts and rock varnish", in D.S.G. Thomas (ed) Arid Zone Geomorphology, Belhaven, London, pp25-55.

Watts N.L. (1977) Pseudo-anticlines and other structures in some calcretes of Botswana and southern Africa, Earth Surface Processes 2:63-74.

------ (1980) Quaternary pedogenic calcretes from the Kalahari (southern Africa), mineralogy, genesis and diagenesis, Sedimentology 27:661-686.

Wayland E.J. (1953) More about the Kalahari, Geographical Journal 119:49-56.

------ (1954) Outlines of pre-history and stone age climatology in the Bechuanaland Protectorate, Memoir Academie Royale des Sciences Coloniales, des Sciences Naturelles et Medicales 25:47.

Weare P. and Yalala A. (1971) Revised vegetation map of Botswana, Botswana Notes and Records 3:131-143.

Weijermars R. (1989) Global tectonics since the breakup of Pangaea 180 Million years ago: evolution maps and lithospheric budget, Earth-Science Review 26:113-162.

Weinberg C. (1975) Fragments of a desert land: memoirs of a South West African doctor, Robert Hale & Co., London, 157pp.

Weir J.S. (1969) Chemical properties and occurrence on Kalahari sand of salt lakes created by elephants, Journal of Zoology 158:293-310.

Wellington J.H. (1955) Southern Africa, a geographical study Vol 1 Physical Geography, Cambridge University Press 528pp.

Werger M.J.A. (1978) "Biogeographical division of southern Africa", in W. Werger (ed) Biogeography and ecology of southern Africa, Junk, The Hague, pp145-170.

Westgate K.N. (1976) Environmental extremes in Bechuanaland Protectorate, 1889-1965, Disaster Research Unit (unpublished), Gaborone.

Whitlow J.R. (1985) Dambos in Zimbabwe. A review, Zeitschrift für Geomorphologie, Supplementband 52:115-146.

Wikner T. (1980) Sand rivers of Botswana - Phase I, Botswana Department of Water Affairs/SIDA, Gaborone.

Wilford G.E. (1991) "Exposure of land surfaces, drainage age and erosion rates", in C.D. Ollier (ed) Ancient Landforms, Belhaven, London. pp99-103.

Williams G.J. (1975) Geomorphology of the southern province of Zambia, Zambian Geographical Association Handbook Series number 4.

Williams L.A., Parks G.A and Crerar D.A. (1985) Silica diagenesis, II. General mechanisms, Journal of Sedimentary Petrology 55:312-321.

Williams M.A.J. (1985) "Pleistocene aridity in tropical Africa, Australia and Asia", in I. Douglas and T. Spencer (eds), Environmental change and tropical geomorphology, Allen and Unwin, London, pp219-233.

Wilkinson M.J. (1988) "Arid landscapes" in B.P. Moon and G.F. Dardis (eds) The geomorphology of southern Africa, Southern Publishers, Johannesburg. pp78-102.

Wilson B.H. and Dincer T. (1976) "An introduction to the hydrology and hydrography of the Okavango delta", in Proceedings of the Symposium on the Okavango delta and its future utilisation, Botswana Society, Gaborone.

Wolman M.G. and Gerson R. (1978) Relative scales of time and effectiveness of climate in watershed geomorphology, Earth Surface Processes 3:189-208.

Wood W.W. and Osterkamp W.R. (1987) Playa lake basins on the Southern High Plains of Texas and New Mexico: Part 2. A hydrologic model and mass-balance arguments for their development, Bulletin of the Geological Society of America 99:224-230.

Wopfner H. (1978) "Silcretes of northern South Australia and adjacent regions", in T. Langford-Smith (ed) Silcrete in Australia, Armidale, Department of Geography, University of New South Wales, pp73-141.

Wopfner H. and Twidale C.R. (1967) "Geomorphological history of the Lake Eyre basin", in J.N.Jennings and J.A. Mabbutt (eds) Landform studies from Australia and New Guinea, Cambridge University Press, pp119-143.

Wright E.P. (1978) Geological studies in the northern Kalahari, Geographical Journal 144:235-250.

Wright V.P. (1989) Terrestrial stromatolites and laminar calcretes: a review, Sedimentary Geology 65:1-13.

Wright V.P. and Tucker M.E. (1991) "Calcretes: an introduction", in V.P. Wright and M.E. Tucker (eds) Calcretes, International Association of Sedimentologists Reprint Series Volume 2, Blackwell Scientific Publications, Oxford, pp1-22.

Yellen J.E. and Lee R.B. (1976) "The Dobe-/Du/da environment", in R.B. Lee and I. De Vore (eds) (1976) Kalahari hunter-gatherers: studies of the !Kung San and their neighbors, Harvard University Press, Cambridge Massachusetts, pp27-46.

Young R.W. (1985) Silcrete distribution in eastern Australia, Zeitschrift für Geomorphologie 29:21-36.

------ (1986) Sandstone terrain in a semi-arid littoral environment: the lower Murchison valley, Western Australia, Australian Geographer 17:143-153.

Zeil P., Volk P. and Saradeth S. (1991) Geophysical methods for lineament studies in groundwater exploration. A case history from S.E. Botswana, Geoexploration 27:165-177.

APPENDIX 1

THIN-SECTIONS: LETLHAKENG VALLEY 1

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 1

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 7.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	47	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	47
3. Pebble	0	3. Silica void-fill	6
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric silcrete. Skeletal quartz grains set in a complex cryptocrystalline silica, disordered chalcedony and microquartz matrix. Chalcedony appears to be a late-stage addition to the matrix, as it is often found near to void spaces and appears to replace the cryptocrystalline matrix constituents. Some particles of older silcrete present as well-rounded grains of microquartz.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some brown-stained coatings on grains, some opalline coatings near to void spaces as early stages of void-fill.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Small but frequent.
	Chalcedony	Void-fill generally consists of a simple opalline silica to length-fast chalcedony to disordered chalcedony sequence. Voids small but usually completely infilled.
	Microquartz	Sometimes present towards the centres of void fills.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 2

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 6.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	63.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	36
3. Pebble	0	3. Silica void-fill	0.5
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, consisting of skeletal quartz grains (plus occasional opaques and rare feldspars) set in an almost isotropic microquartz and/or cryptocrystalline silica matrix. Void fills show late stage infilling by chalcedony which rarely appears well organised.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Rare.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Occasional void fills.
	Chalcedony	Length-fast chalcedony coating void walls, with occasional coalescing spherulites of length-fast chalcedony (showing pseudo-uniaxial extinction crosses) or disordered chalcedony towards void centres.
	Microquartz	Rarely in voids.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 3

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 6.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	37	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	45
3. Pebble	0	3. Silica void-fill	8
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS- to F-Fabric silcrete consisting of skeletal quartz up to 1 mm diameter, with occasional opaques, tourmaline, strongly pleochroic augite, plagioclase and microcline feldspar, set in a disordered chalcedony and almost isotropic cryptocrystalline silica matrix. Chalcedony and opalline void-fills present, which appear to have formed after main body of silcrete - chalcedony or opal forms overgrowths on skeletal quartz grains and also over disordered chalcedony matrix material. Very densely cemented.

Petrographic Features;

1. Embayments/Fretting		Fairly common, particularly evident on larger grains.
2. Grain coating		Many grains show an opalline-silica coating, often with brown staining, apparently an early stage of cementation since the disordered chalcedony matrix has infilled around coated grains.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex void-fills.
	Chalcedony	Common sequence of void fill is as follows; layered opalline silica to length-fast chalcedony to either disordered chalcedony or coalescing spherulites of length-fast chalcedony showing pseudo-uniaxial extinction crosses. Some larger voids show the sequence opal to disordered chalcedony to length-fast chalcedony to megaquartz. At most four distinct layers of void-fill.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 4
LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 5.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	42.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	53
3. Pebble	0.5	3. Silica void-fill	4
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS-Fabric silcrete consisting of skeletal quartz grains (with rare opaques, rounded grains of microquartz - ? recemented silcrete, up to 1 mm diameter) set in a complex opalline silica, cryptocrystalline quartz and disordered chalcedony matrix. Sequence of matrix formation appears to have been opalline coatings of grains followed by infilling by cryptocrystalline quartz with chalcedony finally deposited within voids. Chalcedony was almost certainly deposited later than the quartz matrix.

Petrographic Features;

1. Embayments/Fretting		Occasional.
2. Grain coating		Opalline silica surrounding grains is fairly common.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Commonplace.
	Chalcedony	Void fill generally consists of a laminar opalline coating at void edges; then disordered chalcedony. Some voids contain megaquartz at their centres, but with no abrupt transition from the chalcedony. Chalcedony, where present, is rarely in an ordered condition, suggesting little time for crystal organisation. It often shows a layered appearance, but there is little needle development.
	Microquartz	Occasionally present in between chalcedony and megaquartz in void fills.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 6

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 5.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	45	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	51
3. Pebble	0	3. Silica void-fill	4
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS-Fabric silcrete comprising skeletal quartz grains in a dominantly cryptocrystalline quartz matrix. Many grains show brown-stained rims, which appear to have comprised the first stage of cementation, followed by cementation by cryptocrystalline matrix material.

Petrographic Features;

1. Embayments/Fretting		Occasional evidence of dissolution, particularly on smaller grains.
2. Grain coating		Brown-stained opalline silica grain coatings often present.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Generally small.
	Chalcedony	General sequence of void fill is a thin opal coating on grains followed by either disordered chalcedony or coalescing spherulites of length-fast chalcedony showing pseudo-uniaxial extinction crosses. Some voids show opal coatings with single megaquartz crystals up to 0.75 mm at void centres.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 8

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 4.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	43	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	43
3. Pebble	0	3. Silica void-fill	13
4. Other	0	4. Micro-carbonate	0
Void space (%)	1	5. Carbonate void-fill	0

General Description; GS- to F-Fabric massive silcrete consisting of skeletal quartz grains (with rare microcline and plagioclase feldspar) set in a complex brown-stained cryptocrystalline quartz and microquartz matrix. Some void spaces filled dominantly with chalcedony. Densely cemented. Most skeletal grains are well-rounded.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Many grains show brown-stained ?opalline silica grain coatings, particularly near to void fills.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Fairly common, with two types visible.
	Chalcedony	Type 1 - more common; opalline silica grain coatings overlain by length-fast needle-like chalcedony with an abrupt change to a megaquartz void centre. Type 2; opalline silica grain coating overlain by length-fast chalcedony with a disordered chalcedony void fill centre. Some void centres contain spherulites of length-fast chalcedony with pseudo-uniaxial extinction crosses.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 10

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 4.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	49.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	46
3. Pebble	0.5	3. Silica void-fill	4
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS- to F- fabric massive silcrete. Skeletal quartz grains set in a complex almost isotropic cryptocrystalline silica to disordered chalcedony matrix. One grain of silcrete present comprising microquartz.

Petrographic Features;

1. Embayments/Fretting		Occasional.
2. Grain coating		Opalline silica coatings near to void spaces.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Not extensive but complex fills - up to 6 separate layers of infill.
	Chalcedony	Maximum sequence consists of opalline silica over grains and microquartz matrix, then length-fast chalcedony , then opalline silica, then length-fast chalcedony, then layered opalline silica with disordered chalcedony at void centres. Some voids contain megaquartz at void centre, with individual crystals filling whole voids (up to 1 mm diameter). Some voids contain coalescing spherulites of length-fast chalcedony showing extinction crosses.
	Microquartz	Rare in void fills.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 12

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 3.5
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	32.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	66.5
3. Pebble	0	3. Silica void-fill	1
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; F-fabric massive silcrete. Skeletal quartz grains set in a densely cemented disordered chalcedony and microquartz dominated matrix. No apparent distribution of chalcedony and micro-quartz. Some grains have opalline grain-coating, which appears partly removed by dissolution. Minimal void space. One complex void-fill, containing disordered and length-fast chalcedony.

Petrographic Features;

1. Embayments/Fretting		Fairly common on larger grains.
2. Grain coating		Opalline coatings on some grains, showing dissolution in places.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Only one viewed in section, ca 2 mm diameter.
	Chalcedony	Void fill dominated by disordered chalcedony. Disordered in majority of void, with fibrous length-fast towards centre and in narrow sections of void. Fairly abrupt transition.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 14

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 3.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	50	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	44
3. Pebble	0	3. Silica void-fill	6
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, comprising skeletal quartz grains (occasional feldspar, opaque minerals, tourmaline, apatite) set in a disordered and length-fast chalcedony matrix. Rare patches of microquartz matrix. Complex void fills present (see below).

Petrographic Features;

1. Embayments/Fretting		Occasionally.
2. Grain coating		Some Fe-rich coatings
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Extensive complex void-fills;
	Chalcedony	General sequence of needles of length-fast chalcedony, abrupt change to coalescing spherulites of length-fast chalcedony showing uniaxial extinction crosses, merging into microquartz and into megaquartz at void-fill centre. Full sequence only seen at widest parts of voids, with the two sequences of chalcedony followed by megaquartz or microquartz seen in narrow sections.
	Microquartz	Seen towards the centre of some void fills.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 16

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 2.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	45	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	54.5
3. Pebble	0	3. Silica void-fill	0.5
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete with dominantly quartz grains (some Fe-minerals, rare feldspar and silcrete pebbles) set in a crypto-crystalline silica/disordered chalcedony matrix. Some microquartz matrix, but very localised. Minimal void space. Some patches of brown-stained opalline silica. Little apparent organisation of matrix constituents.

Petrographic Features;

1. Embayments/Fretting		Limited.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		One small void ca 0.2 mm.
	Chalcedony	Disordered chalcedony void-fill.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 18

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 2.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	55	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	38.5
3. Pebble	0	3. Silica void-fill	6
4. Other	0.5	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS- to F-fabric silcrete, with skeletal quartz grains set in an almost isotropic cryptocrystalline silica matrix. Complex void-fills present (see below). Densely cemented.

Petrographic Features;

1. Embayments/Fretting		Occasional.
2. Grain coating		Some opalline silica grain coatings, mainly near voids.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Large and complex.
	Chalcedony	General sequence of void-fill comprises opalline silica coatings on grains or pre-existing matrix, then length-fast chalcedony followed by an abrupt change to a thin layer of opalline silica, then further length-fast chalcedony or disordered chalcedony. Some centres of larger void fills contain microquartz. Generally four separate periods of infill. Linear void in centre of section shows eight stages of infill: opalline silica - l.f. chalcedony - opal - l.f. chalcedony - opal -l.f. chalcedony - length-slow chalcedony - megaquartz.
	Microquartz	At the centres of some voids.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 20

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 1.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	53.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	46.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS-Fabric silcrete consisting of slightly fretted skeletal quartz grains (occasional opaques, plagioclase, augite) set in a cryptocrystalline quartz matrix. Matrix often brown-stained; where less stained appears to consist of microquartz. Very few void-fills present - section consists of skeletal grains and cement material.

Petrographic Features;

1. Embayments/Fretting		Occasional.
2. Grain coating		Occasional.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Small voids present.
	Chalcedony	General sequence consists of a very thin opalline silica layer, followed by length-fast chalcedony with disordered chalcedony at void centres.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 22

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 1.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	54.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	44
3. Pebble	0	3. Silica void-fill	1
4. Other	0.5	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS to F-Fabric massive silcrete, with skeletal quartz grains (plus occasional opaques, disordered chalcedony [silcrete] grains) set in a disordered chalcedony and microquartz matrix. Brown-stained laminar opalline silica-chalcedony-megaquartz void fills. Very few unfilled voids.

Petrographic Features;

1. Embayments/Fretting		Some embayments.
2. Grain coating		Very rare.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		A few micro-voids.
	Chalcedony	Void fills consist of laminated brown-stained opalline silica, with an abrupt transition to coalescing spherulites of length-fast chalcedony showing uniaxial extinction crosses. One void contains megaquartz at the centre.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1A
SAMPLE NUMBER: 24

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 7m high, north side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 0.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	56	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	44
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric densely cemented massive silcrete, with skeletal quartz grains (occasional Fe-minerals) in an almost isotropic cryptocrystalline silica matrix. Some areas of disordered chalcedony in matrix. Some larger grains show evidence of grains dissolution or fretting, but crystal overgrowths are rare.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Absent.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE:	LETV1A
SAMPLE NUMBER:	25
LOCATION:	GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE:	24°09'35" S, 25°12'00" E
EXPOSURE TYPE:	Vertical cliff 7m high, north side of amphitheatre valley head.
HEIGHT (m) ABOVE BASE:	0.25
ASSOCIATED STRATIGRAPHY:	Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	59	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	40
3. Pebble	0	3. Silica void-fill	1
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS-Fabric silcrete with skeletal quartz grains in a disordered to length-fast chalcedony matrix. Some grains of silcrete (consisting of disordered chalcedony and microquartz), opaques, apatite also present. Parts of matrix are almost isotropic opalline silica.

Petrographic Features;

1. Embayments/Fretting		Some embayments.
2. Grain coating		Rare.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Rare micro-voids.
	Chalcedony	Disordered chalcedony fills.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE:	LETV1B
SAMPLE NUMBER:	1
LOCATION:	GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE:	24°09'35" S, 25°12'00" E
EXPOSURE TYPE:	Vertical cliff 6.25m high, south side of amphitheatre valley head.
HEIGHT (m) ABOVE BASE:	6.25
ASSOCIATED STRATIGRAPHY:	Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	59	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	41
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete - skeletal quartz grains plus rare plagioclase and opaques in a complex brown-stained cryptocrystalline silica and disordered chalcedony matrix. General appearance of section suggests that cryptocrystalline silica matrix was in place, but not completely filling pore spaces, with a break in silica deposition leaving a partially cemented structure which was later infilled by disordered chalcedony.

Petrographic Features;

1. Embayments/Fretting		Some smaller grains are slightly fretted.
2. Grain coating		Many grains show a brown opalline silica coating, which appears to have initiated cementation of the silcrete.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Common, but generally small.
	Chalcedony	Most void fills consist of an opalline grain coating (also coating areas of matrix material in contact with the void), with disordered chalcedony or megaquartz at the void centre. No abrupt break between void fill and matrix in some parts of section, suggesting possible dissolution around void edges by pore water solutions.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 2

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 5.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	48	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	52
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, with skeletal quartz, fragments of disordered chalcedony (silcrete grains), opaques and occasional feldspars, set in a brown-stained cryptocrystalline silica matrix. Very densely cemented with minor remaining void space.

Petrographic Features;

1. Embayments/Fretting		Some grains have serrated borders.
2. Grain coating		Grains show a brown opalline silica coating, particularly near to infilled voids.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Very small void fills only (ca 0.1 mm).
	Chalcedony	Void fill contain opalline silica grain coating with disordered chalcedony or poorly crystalline spherulites of length-fast chalcedony.
	Microquartz	Absent from voids.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 3

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 5.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	69.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	30.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS- to F-Fabric massive silcrete, with skeletal quartz grains (+opaques, some plagioclase, tourmaline, apatite) set in an almost isotropic brown-stained cryptocrystalline silica matrix. Staining makes identification of matrix material difficult.

Petrographic Features;

1. Embayments/Fretting		Some grains appear slightly fretted.
2. Grain coating		Many grains show brown opalline silica coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Rare and small.
	Chalcedony	Most common sequence is opalline silica at void fringe, with either disordered or length-fast chalcedony inside this. Some voids contain megaquartz at centre.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 4

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 4.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	70	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	30
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, with skeletal quartz grains plus rare opaques and needle-like crystals of tourmaline or apatite set in a complex brown stained cryptocrystalline silica, microquartz and disordered chalcedony matrix. Sequence of matrix formation appears to have been initial cementation by opalline or cryptocrystalline silica with subsequent deposition of microquartz. This deposition halted before the matrix was completely infilled, with later emplacement of disordered chalcedony. Further opalline silica and chalcedony was deposited in void spaces.

Petrographic Features;

1. Embayments/Fretting		Many grains show evidence of dissolution.
2. Grain coating		Opalline grain coatings commonplace.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Usually small.
	Chalcedony	Void fills generally comprise an opalline silica lining followed by length-fast chalcedony with disordered chalcedony or occasional megaquartz at the centre.
	Microquartz	Rare in voids.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 6

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 4.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	61	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	39
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS- to F-Fabric silcrete, with skeletal quartz grains plus some opaques set in a complex almost isotropic brown-stained cryptocrystalline silica and disordered chalcedony matrix. Disordered chalcedony is the dominant matrix constituent, with opalline or cryptocrystalline silica forming grain coatings as an initial cementation of the quartz grains. Void fills also chalcedony, but often in a more organised crystalline form.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Usually opalline silica.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Usually small and simple.
	Chalcedony	Common sequence of fill consists of opalline silica around void fringes with either disordered chalcedony or a zone of disordered chalcedony followed by coalescing spherulites of length-fast chalcedony (showing extinction crosses) at the centre.
	Microquartz	Absent in voids.
	Calcite	Absent.

SAMPLE PROFILE:	LETV1B
SAMPLE NUMBER:	8
LOCATION:	GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE:	24°09'35" S, 25°12'00" E
EXPOSURE TYPE:	Vertical cliff 6.25m high, south side of amphitheatre valley head.
HEIGHT (m) ABOVE BASE:	3.75
ASSOCIATED STRATIGRAPHY:	Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	58.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	40.5
3. Pebble	0	3. Silica void-fill	1
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; F- to GS-Fabric silcrete comprising skeletal quartz grains (plus opaques and occasional silcrete grains consisting of microquartz and disordered chalcedony) set in a complex disordered chalcedony and brown-stained almost isotropic cryptocrystalline silica matrix. Void fills also consist of chalcedony.

Petrographic Features;

1. Embayments/Fretting		Some grains show serrated edges but generally well- to sub-rounded.
2. Grain coating		Many grains show brown opalline coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Mostly small.
	Chalcedony	Fills usually start with opalline silica followed by either disordered or length-fast chalcedony. Some voids show four stages of fill - brown-stained laminar opalline silica, then a thin layer of length-fast chalcedony, then another laminar opalline layer with either disordered chalcedony or cryptocrystalline silica at void centre. One larger void (ca. 0.3 mm) contains megaquartz at its centre.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE:	LETV1B
SAMPLE NUMBER:	10
LOCATION:	GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE:	24°09'35" S, 25°12'00" E
EXPOSURE TYPE:	Vertical cliff 6.25m high, south side of amphitheatre valley head.
HEIGHT (m) ABOVE BASE:	3.25
ASSOCIATED STRATIGRAPHY:	Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	54.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	45.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, with mostly skeletal quartz grains set in an almost isotropic brown-stained cryptocrystalline silica matrix. Very densely cemented with few voids apparent in this section.

Petrographic Features;

1. Embayments/Fretting		Some larger grains show embayments.
2. Grain coating		Most grains have a brown opalline silica coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Usually small and completely infilled.
	Chalcedony	Most voids completely filled with laminated brown-stained opalline silica, with some showing length-fast followed by disordered chalcedony at their centre. One void contains spherulites of length-fast chalcedony.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 12

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 2.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	58	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	41.5
3. Pebble	0	3. Silica void-fill	0.5
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive GS- to F-Fabric silcrete comprising skeletal quartz grains (plus rare opaques, plagioclase) set in a complex cryptocrystalline silica, microquartz and disordered chalcedony matrix. Distribution of different matrix constituents shows no particular pattern, except that chalcedony is generally found nearer to void fills. Microquartz with visible needlepoint extinction is comparatively rare in matrix. Matrix invariably shows layering around skeletal grains under high magnification.

Petrographic Features;

1. Embayments/Fretting		Some embayments but all grains are well- to sub-rounded
2. Grain coating		All grains show initial grain coating of almost isotropic silica
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Few present in section.
	Chalcedony	Some void fills with unstructured opalline silica at void fringes and either disordered chalcedony or coalescing spherulites of length-fast chalcedony showing pseudo-uniaxial extinction crosses at void centres.
	Microquartz	Absent from void fill.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 14

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 2.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	53	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	47
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS-Fabric massive silcrete, densely cemented, with skeletal quartz grains (plus opaques, rare plagioclase, some grains of disordered chalcedony representing pre-existing silcrete) set in a slightly brown-stained cryptocrystalline silica matrix. Some areas of matrix may be disordered chalcedony. Occasional void fills contain disordered chalcedony. Grains show rare grain coatings, but fairly common evidence of grain dissolution.

Petrographic Features;

1. Embayments/Fretting		Fairly frequent.
2. Grain coating		Rarely present, due to evidence of dissolution.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Two types of void fill present.
	Chalcedony	Type 1; Almost isotropic opalline silica void lining with either disordered chalcedony at centre or coalescing spherulites of length-fast chalcedony with extinction crosses. Type 2; Opalline silica void lining with strained megaquartz at void centre (straining probably due to section preparation).
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 16

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 1.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	61	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	38
3. Pebble	0	3. Silica void-fill	0.5
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0.5

General Description; GS- to F-Fabric massive silcrete comprising skeletal quartz grains (plus occasional plagioclase and opaques) set in a microquartz, disordered chalcedony and cryptocrystalline silica matrix. Very well cemented with few void spaces. Matrix is often brown-stained making distinguishing between matrix materials difficult. Majority of matrix is cryptocrystalline silica and microquartz.

Petrographic Features;

1. Embayments/Fretting		Rare, but sometimes apparent on larger grains. Most grains fairly well-rounded.
2. Grain coating		Present on some grains near voids.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		No complex void fills present.
	Chalcedony	Most void fills are small and consist of poorly layered opalline silica with occasional disordered chalcedony at void centres.
	Microquartz	Rarely present.
	Calcite	One void shows possible calcite at very centre of void.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 18

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 1.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	42	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	57.5
3. Pebble	0.5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS- to F-Fabric silcrete - skeletal quartz grains plus opaques, plagioclase and silcrete fragments (made up of disordered chalcedony) set in a dominantly disordered chalcedony matrix. Patches of brown-stained almost isotropic cryptocrystalline silica matrix also present, but degree of staining prevents detailed identification of matrix. Very densely cemented section, with no void fills present - total cementation by chalcedony matrix material.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Rare.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Absent.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1B
SAMPLE NUMBER: 20

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 0.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	56.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	43
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0.5

General Description; Massive GS- to F-Fabric silcrete with skeletal quartz grains plus opaques set in a complex disordered chalcedony and cryptocrystalline silica matrix. Section poor, so distinguishing between matrix types is difficult. Some calcite present in void fills, and possibly replacing matrix material in parts of section.

Petrographic Features;

1. Embayments/Fretting		Rare, with most grains well-rounded.
2. Grain coating		Most grains show very thin brown-stained opalline silica coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Two types present.
	Chalcedony	Type 1; opalline grain coating lining void, with disordered or length-fast chalcedony void fill.
	Microquartz	Generally absent.
	Calcite	Type 2; Opalline void lining with microcrystalline void fill. Little replacement of void lining apparent.

SAMPLE PROFILE: LETV1B
SAMPLE 22

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'35" S, 25°12'00" E
EXPOSURE TYPE: Vertical cliff 6.25m high, south side of amphitheatre valley head.

HEIGHT (m) ABOVE BASE: 0.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari sand, with sand in valley base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	54	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	45
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	1

General Description; Massive GS-Fabric silcrete, consisting of skeletal quartz grains plus rare opaques and silcrete fragments, set in a complex cryptocrystalline silica and disordered chalcedony matrix with partial replacement by calcite in proximity to void spaces. Disordered chalcedony more common in association with calcite.

Petrographic Features;

1. Embayments/Fretting		Some, but grains generally well- to sub-rounded.
2. Grain coating		Near void spaces, grains coated with opalline silica.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Two types present.
	Chalcedony	Absent.
	Microquartz	Some voids contain a lining of opalline silica with a slightly strained megaquartz central void fill.
	Calcite	Two large voids (ca. 0.75 mm diam.) contain opalline silica around fringes with either poorly crystalline or micro-calcite at the centre. Other small voids contain only micro-calcite at the centre. In both cases there is no evidence of dissolution of the void lining. Partial replacement of chalcedony matrix apparent near to calcite fills.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 1

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 6.65
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	13	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	84
3. Pebble	0	3. Silica void-fill	3
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; Complex F-Fabric silcrete, with quartz grains and some opaques and feldspar in a complex almost isotropic cryptocrystalline silica, disordered chalcedony and microquartz matrix. Some parts of the matrix are also deeply Fe-stained, with some stained areas tending to be elongate suggesting deposition along preferential lines. The areas near these Fe-rich zones are generally slightly pink coloured giving a superficial appearance of being a calcitic matrix. It is possible that silica has replaced calcite in these areas, however, the staining precludes identification under the microscope.

Petrographic Features;

1. Embayments/Fretting		Some grains show signs of dissolution.
2. Grain coating		Rare.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Most complex sequence of void fill consists of a layer of length-fast chalcedony, followed by an equal thickness (0.08 mm approx) of opalline silica. Further length-fast chalcedony makes up the centre of the void fill.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 2

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 6.15
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	30	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	64
3. Pebble	0	3. Silica void-fill	6
4. Other	0	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; A massive F-Fabric silcrete, with skeletal quartz grains set in a complex mixed almost isotropic cryptocrystalline silica, microquartz and disordered chalcedony matrix. The matrix material has no particular pattern with a seemingly random sequence. Parts of the matrix are also brown-stained and this makes identification of different matrix constituents difficult.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some grains have brown-stained opalline silica rims, particularly near void spaces.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Many voids are lined by opalline silica, followed by length-fast chalcedony with megaquartz or further length-fast chalcedony at the void centre.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 3

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 5.70
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	22.5
3. Pebble	0	3. Silica void-fill	5
4. Other	0	4. Micro-carbonate	66.5
Void space (%)	0.5	5. Carbonate void-fill	0.5

General Description; Complex "M-Fabric" duricrust with quartz grains set in a highly complex sugary crystalline calcite and disordered chalcedony matrix. The matrix shows clear evidence of the calcite matrix being replaced by chalcedony. There is no clear pattern to the replacement, which does not appear to be related to voids or other structural features. The calcite: chalcedony ratio in the matrix is approximately 3:1. The replacement suggests a complex history of development, which is further enhanced by the structure of void fills.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have calcite grain coatings or brown-stained rims.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Very well developed void fill sequences. Calcite lines the void walls, overlain by a complex multiple sequence of opalline silica. At least five layers or bands of opalline silica are present, distinguished by different colouration. This is followed by megaquartz with an abrupt break to a final calcite infill.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 4

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 5.20
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	41	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	58
3. Pebble	0	3. Silica void-fill	0
4. Other	1	4. Micro-carbonate	0
Void space (%)	0	5. Carbonate void-fill	0

General Description; GS- to F-Fabric massive silcrete with skeletal quartz grains plus occasional opaques and feldspars in a dense complex microquartz, disordered chalcedony and almost isotropic cryptocrystalline silica matrix. There is no apparent pattern to the distribution of matrix types. Some grains show a brown rim around the grain fringe, but the overall appearance is of a simple silica cemented silcrete.

Petrographic Features;

1. Embayments/Fretting		Most grains are well rounded and appear unaltered.
2. Grain coating		Some grains show an Fe-rich coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	No complex void fill sequences present - any fill tends to be simple disordered chalcedony.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 6

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 4.55
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	4
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	91
Void space (%)	0	5. Carbonate void-fill	0

General Description; Sugary crystalline "M-Fabric" calcrete with quartz grains set in a complex variable microcrystalline to sugary to macrocrystalline calcite matrix. Some very well-formed calcite crystals are present as part of the matrix. The matrix also shows local signs of considerable alteration to silica, in the form of disordered chalcedony. This appears to occur mainly in areas of large calcite crystals.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some crystalline calcite grain coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Some voids are filled with length-slow chalcedony.
	Microquartz	Absent.
	Calcite	Many voids away from areas of siliceous replacement are lined with crystalline calcite. Also, the macro-crystalline calcite may be major void fills.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 7

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 4.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	2
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	91.5
Void space (%)	0	5. Carbonate void-fill	0

General Description; Complex calcrete, varying between an "F-" and "M-Fabric". Some quartz grains in a variable sugary and microcrystalline calcite matrix. The matrix contains large (6 mm plus diameter) areas of sugary calcite in circular to oval patches. One of these areas of calcite is being replaced by disordered chalcedony, not in the vicinity of any void space. The patches of sugary calcite contain virtually no quartz grains whereas other brown-stained microcrystalline calcite areas have considerable amounts of quartz. This suggests that the areas of sugary calcite are older - if they had replaced the microcrystalline fabric then the inclusion of grains would be expected.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some grains coated with small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	A fine coating of calcite in voids is common.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 9

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 3.65
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	8.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	4.5
3. Pebble	0	3. Silica void-fill	4.5
4. Other	0.5	4. Micro-carbonate	80.5
Void space (%)	0	5. Carbonate void-fill	1.5

General Description; Complex "F-Fabric" calcrete, with quartz grains plus some opaques set in a microcrystalline calcite matrix with patches of cryptocrystalline silica and disordered chalcedony. The calcite matrix shows a structure composed of large nodules (areas of matrix-dominated calcite up to 1.2 mm across) in places, but is generally sugary in appearance. More quartz-rich duricrust, both in terms of grains and matrix, is found between these large nodules. Parts of this inter-nodule material are almost completely cryptocrystalline silica.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some grains have brown-stained coatings.
3. Glaebules		Absent unless the large nodular features are considered glaebules.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Common void fill sequence comprises a layer of opalline silica, followed by multiple layers of length-fast chalcedony with a microquartz (mainly in linear voids) or megaquartz central void fill.
	Microquartz	See above.
	Calcite	Some completely infilled voids feature large calcite crystals.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 11

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 3.05
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	90
Void space (%)	0	5. Carbonate void-fill	0

General Description; Sugary textured "F-Fabric" calcrete with quartz grains and some opaques minerals set in a crystalline calcite matrix. The matrix shows no sign of replacement by silica, with no evidence of silicification in the section. The size of calcite crystals suggests relatively stable conditions during formation. Parts of the matrix suggest a slightly nodular texture, but this tends to be localised.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated by small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Many larger voids contain macro-calcite crystals (up to 1.2 mm long) suggesting stable conditions during development.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 12
LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 2.75
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	5
4. Other	0	4. Micro-carbonate	84
Void space (%)	1	5. Carbonate void-fill	3

General Description; Massive "M-" to "F-Fabric" composite calcrete. Two types of calcrete are present, one a matrix dominated deeply brown-stained sugary calcite type and the other a large Fe-stained nodular microcrystalline calcite type with more quartz grains. The former type is virtually structure free, whilst the microcrystalline matrix contains evidence of a nodular structure. Complex void fills suggest that silica-rich porewaters were circulating during the latter stages of duricrust development. From the appearance of the overall section, the M-Fabric calcrete must have developed first (it appears as three spherical patches ca. 9 mm diameter), with later emplacement of the quartz grains and more nodular matrix material.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains are coated with small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Void fills tend to be composite, containing chalcedony and/or calcite in variable proportions. Major voids tend to be lined with macro-crystalline calcite, with disordered chalcedony filling the void space. The boundary between the two types is not definite, suggesting possible replacement of the calcite by chalcedony.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 14
LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 2.15
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	2.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	94.5
Void space (%)	0	5. Carbonate void-fill	0

General Description; Sugary textured massive "M-Fabric" crystalline calcrete, with quartz grains and some opaques set in a calcite matrix. The matrix is relatively homogenous, with little variation in crystal size. There is some indication of siliceous replacement with a patch of disordered chalcedony amongst the matrix material, seemingly unrelated to any voids or other structural feature. A variable degree of brown-staining throughout the section.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated with calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent from void fills.
	Microquartz	Absent.
	Calcite	Simple thin coatings of calcite within voids.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 16

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 1.50
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	1
3. Pebble	0	3. Silica void-fill	1
4. Other	0.5	4. Micro-carbonate	92
Void space (%)	0	5. Carbonate void-fill	0

General Description; "M-" to "F-Fabric" massive crystalline calcrete, with quartz grains set in a sugary crystal calcite matrix. The amount of quartz grains present is highly variable, with the calcrete being totally matrix material in places. Some patches of the matrix are microcrystalline calcite, but throughout the majority of the section the calcite crystals are visible at 4x magnification. Some chalcedony void fills indicate circulation of siliceous pore waters.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some small crystals of calcite surround grains.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Major voids filled with macro-crystalline calcite and/or disordered chalcedony.
	Microquartz	Absent.
	Calcite	Some major voids contain calcite, with most small voids being lined by small calcite crystals.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 17

LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)

GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.

HEIGHT (m) ABOVE BASE: 1.25
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	2
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	92
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive "M-Fabric" calcrete with quartz grains and minor opaques set in a sugary crystalline calcite matrix. The matrix is partially stained by Fe. There is evidence of the beginnings of replacement of calcite by silica, with small parts of the matrix being a mix of sugary calcite and disordered chalcedony. This replacement is not in areas associated with voids and appears to be point specific replacement.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated by microcrystalline calcite.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids lined by fine calcite crystals. Some areas which appear to have previously been voids are infilled by macro-crystalline calcite.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 19
LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 0.65
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	
3. Pebble	0	3. Silica void-fill	2.5
4. Other	0	4. Micro-carbonate	94.5
Void space (%)	0	5. Carbonate void-fill	0

General Description; Sugary textured massive "M-Fabric" calcrete. Minor quartz grains plus some opaque minerals set in a crystalline calcite matrix. The matrix is relatively uniform apart from variable amounts of Fe-staining throughout the section. The presence of relatively well-developed calcite crystals in the matrix suggests long-term stability during calcrete formation. Void fills indicate that siliceous pore waters were also present during late stages of development.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated with small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	A major linear void fill contains the following sequence; a layer of disordered chalcedony 0.3 mm thick overlays the calcite matrix material. This is in turn covered by a 0.25 mm layer of well-formed calcite crystals, with their long axes perpendicular to the void wall. Overlying the calcite is a layer of length-fast chalcedony 0.05 mm thick, with a final megaquartz infill. In places, the final siliceous infill is deposited in gaps between well-formed calcite crystals.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV1C
SAMPLE NUMBER: 21
LOCATION: GAOTLHOBOGWE VALLEY (LETLHAKENG VALLEY 1)
GRID REFERENCE: 24°09'27" S, 25°11'28" E
EXPOSURE TYPE: Adjacent to a dammed seasonal pan, north side valley slope. 1.5 m vertical exposure above 15 m slope at 21°.
HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Overlain by Kalahari Sand, with pan sediments in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	86
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	4
Void space (%)	0	5. Carbonate void-fill	0

General Description; Very poor thin-section. F-Fabric massive silcrete with small quartz grains set in a dominantly microquartz and disordered chalcedony matrix. Some small patches of microcrystalline calcite are also present.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have thin silica coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Absent.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Absent.

APPENDIX 2

THIN-SECTIONS: LETLHAKENG VALLEY 2

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 1

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 8.7
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	2	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	96
Void space (%)	0	5. Carbonate void-fill	1.5

General Description; "M-Fabric" massive calcrete, with some quartz grains plus rare opaques in a dense brown-stained microcrystalline calcite matrix. Little evidence of any structure within the calcrete fabric, apart from some later infilling of cracks by calcite. A few small (up to 0.7 mm long) fragments of shell material now replaced by small calcite crystals. Some evidence of Fe-staining within matrix. Fairly few pores.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Some infilling of cracks.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Infilling of cracks within pre-existing calcrete framework by small calcite crystals which can be seen lining walls of voids and cracks. One crack shows two distinct periods of calcite deposition, separated by a slightly darker brown-stained calcite layer.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 3

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 8.05
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	88
Void space (%)	2	5. Carbonate void-fill	5

General Description; Relatively porous massive "M- to F-Fabric" calcrete containing quartz grains and a single fragment of silcrete (consisting of disordered chalcedony) in a brown-stained microcrystalline calcite matrix. One small shell fragment replaced by fine crystalline calcite. One or two small nodules of brown-stained calcite but otherwise a very densely-cemented section.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Matrix is so densely cemented and stained that grain coatings (if present) are not discernible).
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Mostly simple lining of voids by very fine crystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 4

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 7.45
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	89.5
Void space (%)	1	5. Carbonate void-fill	1.5

General Description; Straightforward "M-Fabric" calcrete with very low quartz grain content. Essentially a brown-stained microcrystalline calcite matrix, with occasional quartz grains, some small (up to 0.3 mm) shell fragments now completely replaced by crystalline calcite and some void fills.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Usually simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most small voids are lined with non-stained microcrystalline calcite. One larger void fill (diameter 4.3 mm) contains concentrations of quartz grains plus rust coloured Fe-stained microcrystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 6

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 6.9
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	19	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	76
Void space (%)	0	5. Carbonate void-fill	5

General Description; Massive "F-Fabric" calcrete with quartz grains set in a brown-stained microcrystalline calcite matrix. Matrix has numbers of micro-pores, most of these not being infilled. Gives appearance of being made up of well cemented calcite nodules surrounded by a microcrystalline matrix. However, as matrix is deeply stained it is difficult to establish the history of formation.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some brown-stained microcrystalline calcite coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most void fills are simply lining of voids by microcrystalline calcite, sometimes with Fe-staining.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 8

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 6.40
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	20	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	75.5
Void space (%)	1	5. Carbonate void-fill	3.5

General Description; Massive "F-Fabric" calcrete containing quartz grains plus rare opaques set in a dense brown-stained microcrystalline calcite matrix. A semi-nodular appearance, suggesting development by a combination of the accumulation of calcite nodules and the development and coalescing of calcite grain-coatings. Some Fe-stained areas, which were probably introduced after the development of the overall calcrete structure.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Many grains show a combination of clear crystalline calcite overlain by a brown-stained calcite layer, giving a nodular appearance.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most simple void fills show a fine lining by clear crystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 9
LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 5.90
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	17	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	1
4. Other	0	4. Micro-carbonate	79.5
Void space (%)	0	5. Carbonate void-fill	2.5

General Description; "F-Fabric" calcrete, with quartz grains (plus some plagioclase and opaques) set in a densely cemented brown-stained microcrystalline calcite matrix. Little evidence for nodules within matrix. Some long cracks within matrix infilled by chalcedony, but impossible to tell which type due to dark colouring. Areas of matrix Fe-stained and almost isotropic under crossed-polars.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Matrix too brown-stained to distinguish coatings if present. One grain has a microcrystalline calcite coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Generally simple, but with one complex void fill ca 1.8 mm long.
	Chalcedony	Sequence of void fill seen in thin section is as follows; microcrystalline calcite followed by small calcite crystals followed by brown-stained length-slow chalcedony, a fine layer of brown-stained opalline silica, then length-fast chalcedony with a calcite/chalcedony central fill. Centre of void shows a cleavage pattern identical to that of calcite but birefringences vary between those of calcite and quartz, with patches of low order colours and appearance similar to chalcedony. The retention of the calcite cleavage suggests that the void was originally filled by one calcite crystal which is being replaced by chalcedony.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 11

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 5.65
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	21	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	7.5
4. Other	0	4. Micro-carbonate	67.5
Void space (%)	3	5. Carbonate void-fill	1

General Description; Complex nodular "F-Fabric" calcrete, containing quartz grains and occasional opaques, with extensive evidence for replacement of the calcite matrix by silica. Bulk of section consists of brown-stained nodular calcrete, with the nodules cemented together by microcrystalline calcite. In places, however, the duricrust is dominated by silica, surrounding calcite nodules. The general sequence of the matrix in these parts consists of disordered chalcedony or laminated opalline silica overlying calcite nodules, with occasional length-fast chalcedony present in void fills. The sequence of development of the calcrete shows initial deposition of a calcite dominated framework with subsequent replacement of the matrix material by siliceous deposits. There may have been a further stage of calcite deposition after this, as some voids contain crystalline calcite.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Variable. Some quartz grains have a calcite coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Often complex.
	Chalcedony	As mentioned above, some opalline silica to disordered chalcedony or length-fast chalcedony sequences. Some voids contain opalline silica to chalcedony to crystalline calcite.
	Calcite	Present at the centre of some voids. In areas dominated by calcite nodules, microcrystalline calcite often forms a fine lining to voids.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 13

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 5.00
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	95
Void space (%)	1	5. Carbonate void-fill	0

General Description; "M- to F-Fabric" calcrete containing quartz and rare opaques set in a brown-stained microcrystalline calcite matrix. Structure is clearly composed of coalesced nodules cemented by microcrystalline calcite. Matrix also contains very occasional shell fragments now replaced by calcite.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some brown-stained calcite coatings.
3. Glaebules		One circular glaebular structure present, although this may be an infilled tube or void. Consists of a rim of Fe-stained calcite surrounding a fine calcite matrix.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Generally simple fine calcite lining to voids.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 15

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 4.45
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	13	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	82
Void space (%)	1	5. Carbonate void-fill	4

General Description; "F-Fabric" massive calcrete, with skeletal quartz grains and some opaques set in a dense brown-stained microcrystalline calcite matrix. Matrix generally appears free of any structure, although there is some evidence for nodular structures rimming quartz grains. Some wavy laminations are also present.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some microcrystalline calcite grain coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Generally simple, often interconnected.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some microcrystalline calcite in voids. One void almost completely filled with calcite and quartz grains - possibly infilling by inwashed material.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 16

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 4.15
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	13	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	77.5
Void space (%)	0	5. Carbonate void-fill	9.5

General Description; Massive "M-Fabric" calcrete with quartz grains plus occasional ? tourmaline and opaques set in a dense brown-stained microcrystalline calcite matrix. High proportion of less stained slightly larger crystals of calcite, mostly infilling fine cracks in the calcrete structure. No obvious nodules present, but general appearance suggests formation of a framework of microcrystalline calcite which was subsequently filled by further calcite. Some voids/pores present, but relatively well-cemented overall.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains show a coating or halo of slightly larger calcite crystals separating them from the microcrystalline calcite matrix.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Most voids show some evidence of infilling.
	Chalcedony	One small void is infilled with a sequence of calcite followed by disordered chalcedony.
	Microquartz	Absent.
	Calcite	The majority of voids filled completely or partially by crystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 18

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 3.50
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	89
Void space (%)	1	5. Carbonate void-fill	4

General Description; Straightforward nodular massive "F- to M-Fabric" calcrete containing quartz grains (plus some opaques) set in a microcrystalline calcite matrix. Structure shows evidence of having developed by the gradual coalescing of calcite nodules with infilling by brown-stained microcrystalline calcite.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains are coated by microcrystalline calcite.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Voids are usually partly filled by stain-free microcrystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 20

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 2.90
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	92.5
Void space (%)	2	5. Carbonate void-fill	2

General Description; Massive "M-Fabric" calcrete, with an almost complete absence of quartz grains except in isolated patches. The majority of the section consists of either cemented nodular microcrystalline calcite or microcrystalline calcite with brown-stained wavy laminations. Some interconnected lines of voids within the section.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have brown-stained calcite coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Void fills are generally lined by finely crystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 21

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 2.40
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	81
Void space (%)	5.5	5. Carbonate void-fill	6

General Description; Fairly porous "M-Fabric" calcrete with quartz grains plus minor opaques set in a laminated and nodular microcrystalline calcite matrix. A composite section, with parts of the calcrete showing a brown-stained micro-laminated wavy structure (but without glaebular appearance) and others exhibiting a coalesced nodular form. In the nodular areas, the calcrete appears to have formed as a result of individual nodules of calcite and calcite coated grains being joined together. The junction zone between the two calcrete forms is in the form of a gradual merging rather than an abrupt join, with the laminated calcrete appearing to have formed over the nodular type.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains show a thin microcrystalline calcite coating.
3. Glaebules		Some microcrystalline calcite pellets present with iron stained rims, but no large glaebules.
4. Colloform features		Absent.
5. Void fills		Rarely well-developed, but often voids are interconnected.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some fairly well-formed crystalline calcite in voids, but generally only microcrystalline calcite lining voids.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 23

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.

HEIGHT (m) ABOVE BASE: 2.10
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	1	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	87
Void space (%)	3	5. Carbonate void-fill	9

General Description; Massive "M-Fabric" calcrete, with low quartz content and some opaque minerals present. A brown-stained densely cemented microcrystalline calcite matrix, containing traces of shell material now replaced by less stained microcrystalline calcite. Shape of shell fragments clearly visible.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Some well developed void fill sequences.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Larger voids show a well-formed sequence of microcrystalline calcite infill followed by larger crystals of calcite (up to 0.25 mm diameter). However, many other pores show no evidence for any kind of infill, except perhaps a very thin microcrystalline calcite coating.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 25

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 1.5
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	8	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	80
Void space (%)	8	5. Carbonate void-fill	4

General Description; Massive, porous "M- to F-Fabric" calcrete, containing quartz grains plus occasional opaques in a nodular microcrystalline calcite matrix. Structure of calcrete shows a clear nodular form in places, with calcite infilling gaps in the nodular framework. Nodules approx. 0.2 to 0.3 mm diameter. Some patches of Fe-staining within matrix in a dendritic form.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have dark brown calcite rims with others showing slightly larger crystals of calcite "haloing" them.
3. Glaebules		One large "glaebular" feature created by brown-stained laminar microcrystalline calcite surrounding material identical to remainder of sample. May be that the section has sliced through a dome of rind on the calcrete surface and this feature is not a glaebule.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids are completely or partially filled with crystalline calcite.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 27

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 0.95
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	87.5
Void space (%)	3	5. Carbonate void-fill	2

General Description; Massive complex "M- to F-Fabric" calcrete with quartz grains plus minor opaques set in a partly nodular or simple microcrystalline calcite and partly laminated calcite matrix. The form of the calcrete structures indicate a complex formational history. The initial development appears to have consisted of a simple microcrystalline calcite matrix surrounding quartz grains. These then developed into glaebular structures with the deposition of brown-stained concentric laminar calcite layers around the pre-existing calcite. These laminated calcite layers show breaches in places which cut right through them and into the calcite they surround. The breaches have the appearance of surficial cracks, radiating from (but not penetrating) the approximate centre of the glaebular structure. Following the cracking of the glaebule surface there appears to have been a later stage of calcrete development taking the form of nodular calcite concentrations with a surrounding microcrystalline calcite matrix. This calcite matrix has also been deposited within the cracks in the glaebule, indicating that it developed after the glaebule. An even later stage of formation is indicated by the deposition of crystals of calcite within cracks or voids in the calcrete structure.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		See above.
4. Colloform features		Absent.
5. Void fills		See above.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 29

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 0.70
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	89
Void space (%)	1	5. Carbonate void-fill	2

General Description; Simple massive, slightly porous "M- to F-Fabric" calcrete with quartz grains set in a brown-stained microcrystalline calcite matrix. Very little evidence for a nodular structure and a comparatively simple formation history - a straightforward deposition of microcrystalline calcite around grains.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some fine crystalline linings to voids.

SAMPLE PROFILE: LETV2B
SAMPLE NUMBER: 31

LOCATION: LETLHAKENG VALLEY 2
GRID REFERENCE: 24°08'30" S, 25°03'58" E
EXPOSURE TYPE: East valley flank; 60 m slope at approx 9°.
HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Overlain by thin Kalahari Sand, some sandy soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	77.5
Void space (%)	6	5. Carbonate void-fill	12

General Description; Highly porous "M-Fabric" nodular calcrete. Low quartz grain content and very rare opaque minerals. Calcrete is made up of coalesced nodules of brown-stained microcrystalline calcite not fully cemented together leaving a calcite framework. Very few void fills, those present being comprised of simple calcite.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some brown-stained calcite overgrowths.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Void linings, where present, consist of fine layers of microcrystalline calcite.

APPENDIX 3

THIN-SECTIONS: LETLHAKENG VALLEY 3

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 1
LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.
HEIGHT (m) ABOVE BASE: 3.50
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	26.5	1. Macro-silica	2.5
2. Shell	0	2. Micro-quartz	61.5
3. Pebble	0	3. Silica void-fill	5.5
4. Other	0	4. Micro-carbonate	0
Void space (%)	4	5. Carbonate void-fill	0

General Description; F-Fabric silcrete, with skeletal quartz grains and occasional opaque minerals set in a complex dense brown-stained cryptocrystalline silica and microquartz matrix. The dense brown colour makes it difficult to identify individual areas of each matrix type. By its appearance, this is probably a replacement silcrete, as it possesses a nodular structure in places. It appears that microquartz has replaced the original calcite structure but still leaving features typical of a calcrete.

Petrographic Features;

1. Embayments/Fretting		Some embayments present.
2. Grain coating		Many grains have a deep brown coating.
3. Glaebules		Some nodular features, apparently inherited from a calcrete structure.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Typical sequence of void fill consists of the following; a thin layer (up to 0.1 mm thick) of laminated opalline or cryptocrystalline silica, overlain by length-fast chalcedony (sometimes showing a spherulitic structure with pseudo-uniaxial extinction crosses), with a subsequent layer of opalline silica and sometimes a layer of length-slow chalcedony towards the centre of open voids. In filled voids, the sequence does not go past the second opalline silica phase.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 3
LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.
HEIGHT (m) ABOVE BASE: 2.95
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	32	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	88
3. Pebble	0	3. Silica void-fill	6.5
4. Other	0.5	4. Micro-carbonate	0
Void space (%)	3	5. Carbonate void-fill	0

General Description; F-Fabric massive silcrete, consisting of skeletal quartz plus rare opaques set in an almost isotropic cryptocrystalline silica matrix material which occasionally appears to contain needle-like quartz crystals. Some grains show very thin brown opalline coatings but this is comparatively rare.

Petrographic Features;

1. Embayments/Fretting		Some embayments on larger grains.
2. Grain coating		Some thin brown-stained grain coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Void fill generally comprises opalline silica and chalcedony. Grains and adjacent matrix material are coated by laminated opalline silica (up to 0.15 mm), which tends to be virtually translucent close to the void wall but becomes increasingly brown-stained inwards. This may be due to a gradual change in porewater composition. Within this there is generally a layer (up to 0.05 mm thick) of length-fast chalcedony. Some voids contain an infilling of disordered chalcedony within this.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 4

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 2.70
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	11.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	7.5
3. Pebble	0	3. Silica void-fill	14.5
4. Other	0.5	4. Micro-carbonate	63.5
Void space (%)	2.5	5. Carbonate void-fill	0

General Description; Complex "F-Fabric" calcrete, with quartz set in a dark brown-stained nodular microcrystalline calcite matrix and occasional patches of cryptocrystalline silica. There is some evidence of replacement of calcite by silica, particularly in the vicinity of voids.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some grains have a coating of fine calcite crystals.
3. Glaebules		Nodules present, but no glaebular structures.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	General sequence of void fill consists a layer of laminated opalline cryptocrystalline silica followed by a central fill of either disordered or length-fast chalcedony. Voids tend not to be completely infilled.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 7

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 1.95
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	2.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	15
4. Other	0	4. Micro-carbonate	80
Void space (%)	2.5	5. Carbonate void-fill	0

General Description; Nodular "M-Fabric" calcrete, with few quartz grains plus some opaques in a microcrystalline calcite matrix. The calcrete has a nodular appearance with slightly larger calcite crystals cementing the spaces inbetween (though not fully, as this is a relatively porous rock). Complex void fills indicate circulation of siliceous porewaters, but there is little evidence of replacement.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some grains have a thin layer of small crystals of calcite coating them.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	General sequence of void lining is opalline silica to chalcedony to calcite. The initial opalline silica layer shows laminations, and three separate phases of precipitation. This is followed by length-slow chalcedony, with some voids showing a final fill of crystals of calcite.
	Microquartz	Absent.
	Calcite	Present at the centre of some voids.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 9

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 1.50
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	36
3. Pebble	0	3. Silica void-fill	4.5
4. Other	0	4. Micro-carbonate	56.5
Void space (%)	0	5. Carbonate void-fill	0

General Description; Replacement "M-Fabric" calcrete, with quartz grains in a complex microcrystalline calcite and almost isotropic cryptocrystalline silica matrix. The calcrete shows a nodular appearance in places, and appears to have originally been a simple nodular calcrete cemented by a micro-calcite matrix. Parts of this matrix have now been altered to cryptocrystalline silica giving it a mixed appearance of both high and low order birefringence colours under cross-polarised light. Some void fills also suggest an influx of silica into the porewaters.

Petrographic Features;

1. Embayments/Fretting		Some embayments.
2. Grain coating		Grains within the calcite-dominated parts of the calcrete have coatings of small calcite crystals, whilst opalline silica coatings are common in areas of matrix replacement.
3. Glaebules		Some nodular features.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Void fills often begin with a thin layer of opalline silica followed by length-fast chalcedony and megaquartz.
	Microquartz	Absent.
	Calcite	Absent.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 11

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 1.00
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	1
2. Shell	0	2. Micro-quartz	8.5
3. Pebble	0	3. Silica void-fill	9
4. Other	0.5	4. Micro-carbonate	68
Void space (%)	3	5. Carbonate void-fill	0

General Description; Nodular "F-Fabric" calcrete, with quartz grains set in a microcrystalline calcite matrix. The calcrete appears to have been formed as a coalescing nodular duricrust, with infilling by calcitic matrix material. This appears to have been replaced in places, particularly near to voids, by cryptocrystalline silica although the matrix is still dominated by calcite.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Many void fills contain almost isotropic cryptocrystalline silica, with some having a further layer of length-fast chalcedony and sometimes a central fill of macro-crystalline calcite.
	Microquartz	Absent.
	Calcite	Some voids have central calcite fills.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 13

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 0.45
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	22.5	1. Macro-silica	2
2. Shell	0	2. Micro-quartz	67.5
3. Pebble	0.5	3. Silica void-fill	3.5
4. Other	1	4. Micro-carbonate	1
Void space (%)	2	5. Carbonate void-fill	0

General Description; Complex massive F-Fabric silcrete, with quartz grains plus opaques in a mixed almost isotropic cryptocrystalline silica and microquartz matrix. A composite silcrete with parts of the section rich in small speckles or "crystals" of ? Fe-rich minerals, the remainder being siliceous matrix material. Within the deep brown-stained areas are patches of silcrete with a cryptocrystalline silica matrix, some of which contain nodular structures. These could be inherited from a calcrete, as much of the silcrete has features typical of calcretes.

Petrographic Features;

1. Embayments/Fretting		Many embayments.
2. Grain coating		Some grains have slight brown-stained rims.
3. Glaebules		Maybe some nodular features - possibly inherited from calcrete glaebules.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Void fill generally consists of a laminated opalline silica layer containing some almost spherulitic patches, with disordered or length-fast chalcedony.
	Microquartz	Absent from void fills.
	Calcite	Absent.

SAMPLE PROFILE: LETV3A
SAMPLE NUMBER: 15

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°09'16" S, 25°00'12" E
EXPOSURE TYPE: 3.5 m vertical exposure above debris slope at junction of main valley and western tributary.

HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Top of 22 m debris slope at 18°, grey vertisolic soil in valley bed.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	17	1. Macro-silica	0.5
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	2.5
4. Other	0.5	4. Micro-carbonate	77
Void space (%)	2.5	5. Carbonate void-fill	0

General Description; Simple "F-Fabric" nodular calcrete, with quartz grains plus some opaques set in a microcrystalline calcite matrix. Matrix has a nodular appearance, but the spaces between nodules have been densely infilled by material of similar appearance to the nodules themselves. Some siliceous void fills but little evidence of replacement.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains show thin coatings of small calcite crystals.
3. Glaebules		Nodules present but not really glaebules.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	General sequence of fill consists of a very thin layer of laminated cryptocrystalline silica, followed by length-fast chalcedony.
	Microquartz	Absent.
	Calcite	Some small voids are lined by small calcite crystals.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 1

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.
HEIGHT (m) ABOVE BASE: 5.55
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	13	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	5.5
3. Pebble	0	3. Silica void-fill	7.5
4. Other	0	4. Micro-carbonate	70
Void space (%)	1.5	5. Carbonate void-fill	2.5

General Description; Complex duricrust, varying between "F-Fabric" to almost "GS-Fabric" in places. Majority of section is made up of quartz grains set in a brown-stained nodular microcrystalline calcite matrix. This shows a typical calcrete structure of coalescing nodules. However, in parts of the section, the calcite has been replaced by a complex mixture of microquartz and almost isotropic cryptocrystalline silica. In many places, the calcite nodules are surrounded by silica matrix whilst still retaining their nodular appearance, thus predating the siliceous infill. Some complex void fills also indicate the influence of silica-rich porewaters at late stages of the duricrust development.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Variable. Within calcite-rich parts of the section there are many grains with calcite overgrowths. However, in the parts with silica replacement, opalline or cryptocrystalline silica grain coating are common.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Most linear voids have the following sequence of fill - a layer of laminated opalline silica followed by microcrystalline calcite. Enclosed voids are often more complex with a layer of opalline silica overlain by length-fast chalcedony and a further layer of laminated opalline silica.
	Calcite	Present in some linear voids.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 3
LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.
HEIGHT (m) ABOVE BASE: 5.00
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	6
4. Other	0	4. Micro-carbonate	83.5
Void space (%)	1.5	5. Carbonate void-fill	2

General Description; Nodular "M- to F-Fabric" calcrete with quartz grains set in a nodular brown-stained microcrystalline calcite matrix. Calcrete has developed as a series of coalescing nodules. Some parts of the matrix show partial alteration by silica-rich waters, but still retains its nodular appearance. Complex void fills provide further evidence for the influence of siliceous waters during the evolution of the calcrete.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a fine coating of small calcite crystals. In areas with partial silica replacement, particularly near voids, grains show an opalline silica coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Some linear voids show three phases of opalline silica or chalcedony deposition. These are separated by hiatuses indicated by a thin brown-stained layer. The final void fill is usually length-fast chalcedony. Two sub-circular voids contain a complete fill consisting of opalline silica followed by length-slow chalcedony with calcite completing the void fill.
	Microquartz	Absent.
	Calcite	Present at void centres.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 4

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 4.7
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0.5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	87.5
Void space (%)	2.5	5. Carbonate void-fill	4

General Description; "M-Fabric" nodular calcrete. Quartz grains plus some rare opaques in a microcrystalline calcite matrix. A coalesced nodular calcrete with cementation by microcrystalline calcite and some small visible calcite crystals in spaces between nodules.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Very few void fills, but those present consist of small calcite crystals lining void walls.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 7

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 3.95
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0.5
3. Pebble	0	3. Silica void-fill	4
4. Other	0	4. Micro-carbonate	85.5
Void space (%)	1	5. Carbonate void-fill	3

General Description; Nodular calcrete with quartz grains plus occasional opaques in a brown-stained microcrystalline calcite matrix. "M-Fabric". Nodules are clearly discernible, with microcrystalline calcite cementing them together to form a dense structure. Evidence for circulation of silica-rich waters provided by siliceous void fills.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have small calcite crystals coating them.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Sequence of void fill consists of a layer of laminated almost isotropic opalline silica, followed by length-slow chalcedony with a calcite central void fill.
	Microquartz	Absent.
	Calcite	Sometimes at centre of void fills.

SAMPLE PROFILE: LETV3B
SAMPLE 9

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 3.45
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	90
Void space (%)	0	5. Carbonate void-fill	7

General Description; Nodular "M-Fabric" calcrete with quartz grains in a nodular brown-stained microcrystalline calcite matrix. Calcrete has developed as a series of coalescing nodules, with interstitial cement by calcite matrix material. Some traces of small calcite crystals in infilled spaces between nodules, but otherwise very little evidence for void filling.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a fine microcrystalline calcite grain coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some voids have traces of small calcite crystals as a lining.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 11

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 2.90
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	92
Void space (%)	0	5. Carbonate void-fill	4

General Description; Nodular "M-Fabric" calcrete with quartz grains and occasional opaques set in a dense microcrystalline calcite matrix. Structure of calcrete shows clear nodules which have coalesced to form a dense duricrust. Some patches of small calcite crystals inbetween nodules.

Petrographic Features;

1. Embayments/Fretting		Fretting infrequent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some voids contain a thin lining of calcite crystals.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 13

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.
HEIGHT (m) ABOVE BASE: 2.45
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	89
Void space (%)	3	5. Carbonate void-fill	3

General Description; Densely cemented nodular "M- to F-Fabric" calcrete with quartz, feldspar and opaques mineral grains set in a brown-stained microcrystalline calcite matrix. Typical cemented calcrete structure, with clearly defined irregular nodules and microcrystalline calcite matrix material. No evidence of silica replacement or circulation of Si-rich porewaters.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have either brown-stained microcrystalline calcite rims or more commonly a coating of small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some voids lined with calcite crystals.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 15

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.
HEIGHT (m) ABOVE BASE: 2.05
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	11	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	85
Void space (%)	3	5. Carbonate void-fill	1

General Description; Nodular "F-Fabric" calcrete. Some quartz and strained feldspar grains in a slightly brown-stained calcite matrix. Typical nodular calcrete structure, with nodules coalescing to form a dense network cemented by microcrystalline calcite. Some infrequent infills of chalcedony suggest that siliceous porewaters may have been present during later stages of calcrete development.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have calcite coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Two void fill types - firstly, a fill of disordered chalcedony, which simply lines and/or fills the void.
	Microquartz	Absent.
	Calcite	Secondly, most voids have a thin lining of crystalline calcite.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 17

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 1.55
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	90
Void space (%)	5	5. Carbonate void-fill	0.5

General Description; Nodular calcrete with quartz grains in a nodular brown-stained microcrystalline calcite matrix. "M-Fabric". Some traces of shell fragments evident. Calcrete shows a very clearly defined nodular structure, with most nodules outlined by a thin brown-stained calcite layer. This suggests that at a late stage of the nodule development, water slightly richer in Fe was circulating. The nodules are cemented by a less brown-stained crystalline calcite matrix, which coats some nodules.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Many voids lined with small calcite crystals.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 18

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 1.05
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	0.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	90.5
Void space (%)	2	5. Carbonate void-fill	7

General Description; Nodular "M-Fabric" calcrete with quartz grains set in a nodular microcrystalline calcite matrix. Densely cemented by microcrystalline calcite, with nodules only clearly defined in a few places. No evidence of silica-rich waters, and a comparatively simple development history.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a fine crystalline calcite coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some small crystals lining voids.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 20

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 0.55
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	0.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	93.5
Void space (%)	2	5. Carbonate void-fill	4

General Description; Nodular "M-Fabric" calcrete. Some quartz grains and occasional opaques set in a fine brown-stained microcrystalline calcite matrix. Nodules are irregularly shaped, with microcrystalline calcite cementing them relatively densely together. Numerous fragments of shell present, including one apparently intact bivalve with both valves still hinged together. A simple development history with little in the way of void fills etc.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated with fine crystalline calcite.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some voids have a fine calcite infill, which is often brown-stained suggesting the circulation of Fe-rich porewaters.

SAMPLE PROFILE: LETV3B
SAMPLE NUMBER: 22

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'25" S, 25°00'19" E
EXPOSURE TYPE: 4 m vertical cliff above 1.25m of sloping outcrop, at top of 15 m debris slope (23°), west side.

HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Grey vertisolic soil in valley bed, Kalahari Sand above.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	91
Void space (%)	1	5. Carbonate void-fill	4.5

General Description; Nodular to massive "M-Fabric" calcrete with quartz grains, shell fragments and some opaque minerals set in a slightly brown-stained microcrystalline calcite matrix. Matrix shows that the calcrete is composed of coalesced nodules, with some patches having brown stains, possibly indicative of Fe-staining. Shell fragments are infrequently seen throughout the section, partly replaced by calcite. None of the fragments seen (all apparently bivalve or brachiopod shells) are longer than 1.1 mm.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some voids are lined with small calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 1

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 13.50
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	45.5
3. Pebble	0	3. Silica void-fill	3.5
4. Other	0	4. Micro-carbonate	38
Void space (%)	0	5. Carbonate void-fill	2.5

General Description; Nodular "F-Fabric" calcrete with quartz grains (plus some opaques) set in a mixed brown-stained microcrystalline calcite and sugary crystalline calcite matrix. Calcrete has clearly developed as a series of coalescing nodules, with further microcrystalline and crystalline calcite precipitated between nodules. Some evidence of replacement by chalcedony in the vicinity of void spaces.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains show coatings of calcite crystals.
3. Glaebules		Nodules present but not obvious glaebules.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Complex void fills commencing with an incomplete layer of crystalline calcite. This is overlain by a thin layer of almost isotropic cryptocrystalline silica, followed by laminated opalline silica, then length-fast chalcedony, with the final void fill consisting of calcite in some voids. Other voids have a simple crystalline calcite fill.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 4
LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 13.05
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	18.5
3. Pebble	0	3. Silica void-fill	1.5
4. Other	0	4. Micro-carbonate	73
Void space (%)	0	5. Carbonate void-fill	3.5

General Description; Complex "M-Fabric" calcrete, with quartz grains and minor opaques set in mixed calcite and chalcedony matrix. The calcite shows nodular structures away from the chalcedony-rich areas, with brown-stained microcrystalline calcite nodules cemented by further microcrystalline calcite. A roughly spherical area where disordered chalcedony has replaced calcite is also present. Within the chalcedony matrix there are traces of laminar brown-stained microcrystalline calcite which formerly encircled nodules, giving a vein-like appearance and clearly indicating replacement of calcite by chalcedony.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains and nodules away from the chalcedony-rich area show slightly brown stained rims.
3. Glaebules		Nodules present.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	In addition to the complicated pattern of replacement, there is a complex calcite-chalcedony void fill sequence. Cracks within the chalcedony matrix area are lined with a thin layer of brown-stained calcite followed by length-slow chalcedony which is overlain by an infilling of brown-stained microcrystalline calcite.
	Microquartz	Absent.
	Calcite	See above.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 7

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 12.60
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	2.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	89
Void space (%)	2	5. Carbonate void-fill	6.5

General Description; Simple nodular "M-Fabric" calcrete with some quartz grains set in a brown-stained microcrystalline calcite matrix. The matrix contains a variable amount of staining, with some more densely stained areas appearing to be nodular. Some completely infilled voids.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Possibly some nodular structures of brown-stained microcrystalline calcite.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Small voids infilled by crystalline calcite.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 11

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 12.00
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	7	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	2
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	81
Void space (%)	3	5. Carbonate void-fill	7

General Description; Nodular "M- to F-Fabric" calcrete. Structure is variable, with parts of the section exhibiting a simple nodular structure with coalesced nodules of brown-stained microcrystalline calcite with a slightly less stained matrix of calcite (with varying crystal size). Other parts are less nodular and comprise wavy laminations of brown-stained material. The laminar material shows no obvious overall shape or structure and does not appear to be part of a major glaebule. There is no abrupt join between the two types of calcrete present, with a gradual transition between the two types occurring.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Nodules present, but the wavy laminations do not appear to be part of a glaebule.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most void fills comprise a simple coating by small calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 14

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 11.50
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	81.5
Void space (%)	7	5. Carbonate void-fill	8.5

General Description; Nodular "M-Fabric" calcrete, containing relatively few quartz grains. A simple open, porous calcrete structure, quite clearly made up of a combination of coalescing nodules of brown-stained microcrystalline calcite and partial infilling by crystalline calcite. Very few void fills, suggesting a comparatively simple history of development.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains coated with small calcite crystals.
3. Glaebules		Nodules present, but no major glaebules.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids have a lining of small crystals of calcite- very few voids are completely infilled.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 17

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 11.05
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	3.5
3. Pebble	0	3. Silica void-fill	3.5
4. Other	0	4. Micro-carbonate	84.5
Void space (%)	1	5. Carbonate void-fill	1

General Description; Nodular massive "M- to F-Fabric" calcrete, with quartz grains plus some opaques set in a nodular brown-stained microcrystalline calcite matrix. Nodules have coalesced to produce an interlocking fabric, with interstitial microcrystalline calcite. Some void fills containing chalcedony suggest possible silica replacement of calcite in places.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains and nodules have small crystals of calcite coating them.
3. Glaebules		Nodules present, but no major glaebules.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	General sequence of infill consists of almost isotropic cryptocrystalline silica followed by length-fast chalcedony, often with a disordered chalcedony central fill.
	Microquartz	Absent.
	Calcite	Generally absent except for a few minor simple void fills.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 19

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 10.50
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	12.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	1.5
3. Pebble	0	3. Silica void-fill	7.5
4. Other	0	4. Micro-carbonate	67.5
Void space (%)	7.5	5. Carbonate void-fill	3.5

General Description; Nodular "F-Fabric" calcrete with quartz grains plus some opaques set in a complex microcrystalline calcite matrix, with some patches of chalcedony replacement. Nodules (some of which are coated with small calcite crystals) have been cemented together by lighter coloured brown-stained microcrystalline calcite matrix material. There is some evidence of chalcedony replacement in places, with disordered chalcedony replacing the matrix material but leaving the brown-stained nodules unaltered.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some nodules and grains coated with small calcite crystals.
3. Glaebules		Nodules present, some having a laminated glaebular appearance.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Some voids lined by laminar opalline silica with a length-fast chalcedony infill. These void fills are found within both calcite dominated and chalcedony-rich areas.
	Microquartz	Absent.
	Calcite	Some small simple void fills consisting of calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 21

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 9.80
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	9	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	85
Void space (%)	2	5. Carbonate void-fill	4

General Description; Nodular "M-Fabric" calcrete with quartz grains set in a brown-stained microcrystalline calcite matrix. Calcrete clearly developed as a series of coalescing nodules, cemented by a combination of microcrystalline and small sugary crystals of calcite. A fairly simple history of development is indicated by relatively simple void fills.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Nodules present but not glaebules.
4. Colloform features		Absent.
5. Void fills		Generally simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most common sequence of fill consists of small crystals of calcite either lining or infilling voids. Some voids show traces of Fe-stained material overlying this calcite, possibly indicative of a later period of void lining.

SAMPLE PROFILE:	LETV3C
SAMPLE NUMBER:	22
LOCATION:	MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE:	24°08'04" S, 25°00'20" E
EXPOSURE TYPE:	East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.
HEIGHT (m) ABOVE BASE:	9.60
ASSOCIATED STRATIGRAPHY:	Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	71
Void space (%)	2	5. Carbonate void-fill	17

General Description; Nodular "M- to F-Fabric" calcrete with complex void fills. Grains of quartz set in a nodular microcrystalline calcite matrix. Many grains and some nodules have small calcite crystal coatings. Calcrete has clearly developed as a series of coalescing nodules with later influxes of Ca-rich porewaters creating complex void fills.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains and nodules have a thin coating of small calcite crystals.
3. Glaebules		Nodules present but no glaebular structures.
4. Colloform features		Absent.
5. Void fills		Complex and simple fills present, the former found in continuous cracks.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most complex void fill suggests at least three periods of calcite emplacement within voids. A layer of large calcite crystals (up to 0.4 mm thick) overlies the nodular calcrete. This is overlain abruptly by a 0.1 mm layer of Fe-stained material, most likely calcite. Overlying this is a final infilling of microcrystalline calcite, although this latter infill is only present in larger voids or cracks, the others commonly being filled.

SAMPLE PROFILE:	LETV3C
SAMPLE NUMBER:	24
LOCATION:	MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE:	24°08'04" S, 25°00'20" E
EXPOSURE TYPE:	East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.
HEIGHT (m) ABOVE BASE:	9.10
ASSOCIATED STRATIGRAPHY:	Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	86
Void space (%)	3	5. Carbonate void-fill	8

General Description; Nodular "M-Fabric" calcrete with rare quartz grains in a slightly brown-stained microcrystalline calcite matrix. Structure of section shows that the calcrete has clearly developed as a series of coalescing nodules cemented by microcrystalline calcite. In some places, the cementation has been by larger sugary textured patches of calcite crystals.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Calcrete composed of nodules, but no large glaebules present.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Voids either infilled or lined with small calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 26

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.
HEIGHT (m) ABOVE BASE: 1.80
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	85.5
Void space (%)	1	5. Carbonate void-fill	9.5

General Description; Nodular "M-Fabric" calcrete with quartz grains set in a nodular brown-stained microcrystalline calcite matrix. Calcrete has developed by a gradual joining of calcite nodules, with microcrystalline calcite deposited in spaces within the nodular lattice.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Nodules present, but not glaebules.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some simple but very well formed void fills of macrocrystalline calcite, with calcite crystals up to 0.15 mm across. Most voids lined with small calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 28

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)
GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.
HEIGHT (m) ABOVE BASE: 1.25
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	8.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	82.5
Void space (%)	2	5. Carbonate void-fill	7

General Description; Nodular "F-Fabric" calcrete with relatively few quartz grains plus occasional opaques, set in a nodular brown-stained microcrystalline calcite matrix. Calcrete has clearly developed by the progressive coalescing of microcrystalline calcite nodules. Structure comparatively simple.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains and nodules have a fine coating of small calcite crystals surrounding them.
3. Glaebules		Some very large nodules (up to 3.9 mm) but none showing a glaebular structure.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids are partially lined with small calcite crystals.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 29

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 1.00
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	8.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	83.5
Void space (%)	1	5. Carbonate void-fill	7

General Description; Simple "F-Fabric" calcrete with quartz grains and some opaque minerals set in a slightly brown-stained microcrystalline calcite matrix. Bulk of sample consists of matrix material, interspersed with areas of less stained crystalline calcite, mostly in association with void fills. Very little structure.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most void fills consist of a simple filling with structureless crystalline calcite.

SAMPLE PROFILE: LETV3C
SAMPLE NUMBER: 30

LOCATION: MOSHANENG VALLEY (LETLHAKENG VALLEY 3)

GRID REFERENCE: 24°08'04" S, 25°00'20" E
EXPOSURE TYPE: East valley flank above dammed seasonal pan; from top, 16 m slope at 9°, 2.25 m vertical exposure, 31 m debris slope at 13°, 2.25 m outcrop.

HEIGHT (m) ABOVE BASE: 0.70
ASSOCIATED STRATIGRAPHY: Kalahari Sand above and grey pan sediments at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	1.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	83.5
Void space (%)	2	5. Carbonate void-fill	13

General Description; Nodular "M-Fabric" calcrete. Grains of quartz set in a dense brown-stained nodular microcrystalline calcite matrix. Structure shows clear nodules, up to 0.9 mm diameter cemented by microcrystalline calcite. Some patches of later infill by small calcite crystals.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have a coating of small calcite crystals.
3. Glaebules		Nodules present but no major glaebules.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Voids filled by small calcite crystals.

APPENDIX 4

THIN-SECTIONS: AUOB VALLEY

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: A

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 9.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	80
Void space (%)	1	5. Carbonate void-fill	4

General Description; Complex composite "F- to M-Fabric" calcrete with grains of quartz (one grain 3.6 mm long) and some opaque minerals set in a highly variable partly nodular, partly crystalline calcite matrix. The bulk of the section consists of nodular brown-stained microcrystalline calcite with overlying and entwining swirling wavy brown-stained calcite laminations. The calcrete gives the appearance of being made up of areas of nodules surrounded by stained calcite laminations. Patches of this nodular material are cemented together by more crystalline calcite presumably precipitated at a later date.

Petrographic Features;

1. Embayments/Fretting		Some grains appear highly fretted.
2. Grain coating		Absent.
3. Glaebules		Some nodules present, though no identifiable glaebular structures.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids are partly infilled by sugary calcite crystals.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: B

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 8.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	9.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	6
3. Pebble	0	3. Silica void-fill	1
4. Other	0.5	4. Micro-carbonate	82.5
Void space (%)	0	5. Carbonate void-fill	0.5

General Description; Complex massive "F-Fabric" calcrete with quartz grains set in a brown-stained microcrystalline calcite matrix. Matrix has a partly nodular appearance, with a sugary calcite matrix also present. Complex evolutionary history indicated by grain coatings and void fills, as described below.

Petrographic Features;

1. Embayments/Fretting	Rare.
2. Grain coating	Many grains have elongate calcite crystal overgrowths, radiating at right angles from the grain surfaces. This coating is surrounded by matrix material.
3. Glaebules	Absent.
4. Colloform features	Absent.
5. Void fills	Four (possibly five) separate depositional events are indicated by void fills. Firstly, a layer of disordered chalcedony was deposited over the sugary calcite void surface. This was followed by a stage of calcite crystal growth, with the development of crystals up to 0.5 mm long. This was in turn followed by further disordered chalcedony deposition, with a gradual transition to megaquartz. This forms the last deposit in most voids, but some contain an additional final deposit of microcrystalline calcite.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: C
LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.
HEIGHT (m) ABOVE BASE: 7.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:
Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	47
3. Pebble	0	3. Silica void-fill	3
4. Other	0	4. Micro-carbonate	41
Void space (%)	0	5. Carbonate void-fill	6

General Description; Complex composite "F-Fabric" calcrete with quartz grains set in a mixed sugary calcite and calcite/cryptocrystalline silica matrix where the silica appears to be replacing calcite. The section contains two main calcrete types; one, a matrix dominated brown-stained type with the calcite being replaced by cryptocrystalline silica, and the other a nodular micro-crystalline calcite in a crystalline matrix with quartz and opaque minerals. Complex void sequences are also present.

Petrographic Features;

1. Embayments/Fretting	Absent.
2. Grain coating	Some brown-stained calcite in the nodular calcrete.
3. Glaebules	Absent.
4. Colloform features	Absent.
5. Void fills	Complex, mostly in cracks, some of which cut through one another. Two types of void fill present, both in cracks. One comprises four sequences of fill, with a layer of disordered chalcedony followed by brown-stained laminated chalcedony, then further disordered chalcedony with megaquartz or disordered chalcedony at the centre. The other type of fill contains large crystals of calcite completely infilling the void. Both types reach thicknesses of 0.5 mm. Further complicating these two fills are areas where chalcedony merges into calcite within the same crack, the chalcedony in the narrower part of the void. At one point, two cracks cross, both containing chalcedony.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: D

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.
HEIGHT (m) ABOVE BASE: 6.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	2.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	97
Void space (%)	0	5. Carbonate void-fill	0

General Description; Simple massive "M-Fabric" calcrete containing very few quartz grains and even rarer opaque minerals in a fine sugary crystalline calcite matrix. The calcrete is almost structureless, with a uniform matrix material throughout. Some patches of larger calcite crystals are present at the edge of the section, possibly bounding a former void broken during sectioning.

Petrographic Features;

1. Embayments/Fretting		Some grains appear slightly fretted.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Very small pores appear to be infilled by slightly larger calcite crystals.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: E

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 5.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	0
3. Pebble	1	3. Silica void-fill	1
4. Other	0	4. Micro-carbonate	83.5
Void space (%)	4	5. Carbonate void-fill	7

General Description: Massive "M- to F-Fabric" calcrete, with skeletal quartz grains and occasional opaques set in a sugary crystalline calcite matrix. Matrix is generally quite coarse, suggesting time for calcite crystal growth. Very simple structure, with little evidence of either nodular growth or alteration.

Petrographic Features;

1. Embayments/Fretting		Many grains appear serrated.
2. Grain coating		Some grains have slightly larger than average crystals growing around them.
3. Glaebules		Some brown-stained structureless glaebules.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Most voids are partially filled by calcite crystals.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: F

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 4.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	8	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	2
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	89
Void space (%)	1	5. Carbonate void-fill	0

General Description; "M- to F-Fabric" massive calcrete with occasional quartz grains and rare opaques set in a dominantly brown-stained microcrystalline calcite matrix. The bulk of the section consists of this brown-stained matrix, interspersed with macro-crystalline void fills and areas of sugary crystalline calcite associated with these voids. Some grains within the microcrystalline matrix show Fe-stained grain rims.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some grains have an Fe-stained grain coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Major void fills tend to be almost completely filled with macro-crystalline calcite which exhibits little evidence of any structure.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: G

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 3.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	16.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	6.5
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	77
Void space (%)	0	5. Carbonate void-fill	0

General Description; A composite "F-Fabric" massive calcrete, with quartz grains plus opaques set in a complex macro-crystalline and microcrystalline calcite matrix. Large areas of the section consist of brown-stained microcrystalline calcite with no discernible structure. The are interspersed with a matrix infill of sugary calcite crystals, up to 0.8 mm across. This sugary calcite also infills (partly) many voids. It appears that the brown-stained calcite predates the bulk of the calcrete.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Some brown-stained microcrystalline calcite coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Voids partially filled with crystalline calcite.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: H

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 2.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	23.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	11
3. Pebble	0	3. Silica void-fill	0.5
4. Other	0.5	4. Micro-carbonate	62.5
Void space (%)	2	5. Carbonate void-fill	0

General Description; Complex massive nodular F-Fabric cal-silcrete, with skeletal quartz set in a mixed Fe-stained calcite and disordered chalcedony matrix. The Fe-staining makes determination of the proportion of matrix types very difficult. However, it appears that the duricrust was initially more calcite rich, and has experienced partial replacement by the chalcedony.

Petrographic Features;

1. Embayments/Fretting		Grains are frequently angular and possibly embayed.
2. Grain coating		Some grains have brown-stained coatings.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Where void fills are present they generally consist of calcite lining voids.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: I

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 1.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	10	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	7
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	81
Void space (%)	0	5. Carbonate void-fill	1.5

General Description; Massive "F-Fabric" calcrete, with quartz grains (plus occasional opaques and augite) set in a sugary calcite matrix. A composite form, with patches of dense brown-stained microcrystalline calcite in amongst the more sugary textured calcite which dominates the section. Some parts of the section show considerable Fe-staining. Also amongst the calcite matrix are macro-calcite crystals up to 1.2 mm across, suggesting either a long formation time or long-term stability of pore water conditions. Some evidence of possible silica replacement, with a small area of disordered chalcedony present.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some crystalline calcite around grains but not strictly a grain coating.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Simple.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Voids generally contain a thin lining of crystalline calcite.

SAMPLE PROFILE: AUOB 115
SAMPLE NUMBER: J

LOCATION: KALKHEUVAL FARM, AUOB
GRID REFERENCE: 24°45'45" S, 18°44'10" E
EXPOSURE TYPE: West valley flank, 5.5 m vertical exposure above 3.5 m sloping exposure above debris slope at 27°.

HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Debris slope below expo, with thin soil/valley seds at base.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	10
3. Pebble	0	3. Silica void-fill	3
4. Other	0	4. Micro-carbonate	82
Void space (%)	0	5. Carbonate void-fill	0

General Description; Massive "F- to M-Fabric" calcrete with quartz grains and some opaques in a sugary crystalline calcite matrix. The overall structure of the matrix suggests a long time for calcite development. There is some indication of calcite replacement by cryptocrystalline silica in one part of the section, where quartzitic extinction is evident particularly near to cracks containing siliceous void fill.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Two types, both simple.
	Chalcedony	Minor voids/cracks appear filled with disordered chalcedony.
	Microquartz	Absent.
	Calcite	Other voids contain sugary crystalline calcite.

APPENDIX 5

THIN-SECTIONS: OKWA VALLEY

SAMPLE PROFILE: OKWA2
SAMPLE NUMBER: A

LOCATION: GOBOLOLO CATTLEPOST, OKWA VALLEY
GRID REFERENCE: 22°24'00" S, 20°54'15" E
EXPOSURE TYPE: South bank terrace, 6 m slope at 6°.
HEIGHT (m) ABOVE BASE: 0.60
ASSOCIATED STRATIGRAPHY: Gently sloping terrace level above, valley bed seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	2	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	1.5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	94.5
Void space (%)	1	5. Carbonate void-fill	0.5

General Description; Massive "M-Fabric" calcrete with minor amounts of skeletal quartz and shell fragments (up to 1.4 mm long) set in a brown-stained dominantly micro-calcite matrix. Macro-calcite has been deposited in some cracks within the calcrete. One glaebule is present, as a concentration of quartz grains with laminar calcite around it.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		One 4 mm diameter glaebule present, consisting of a concentration of quartz grains surrounded by laminar calcite.
4. Colloform features		Absent.
5. Void fills		Some more crystalline calcite in planar voids, but otherwise well cemented.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some deposition of calcite as small crystals in cracks.

SAMPLE PROFILE: OKWA2
SAMPLE NUMBER: C

LOCATION: GOBOLOLO CATTLEPOST, OKWA VALLEY
GRID REFERENCE: 22°24'00" S, 20°54'15" E
EXPOSURE TYPE: South bank terrace, 6 m slope at 6°.
HEIGHT (m) ABOVE BASE: 0.40
ASSOCIATED STRATIGRAPHY: Gently sloping terrace level above, valley bed seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	3	1. Macro-silica	0
2. Shell	1.5	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	84
Void space (%)	2.5	5. Carbonate void-fill	9

General Description; Massive "M-Fabric" calcrete, comprising skeletal quartz and shell fragments (including complete gastropods up to 1.8 mm long) set in a brown-stained micro-calcite matrix. Well-cemented, but with several unfilled voids. Major glaebule present.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		One major glaebule, maximum diameter 7.2 mm, comprising a cluster of quartz grains surrounded by laminated calcite. Centre of void contains almost isotropic iron-stained calcite in a fibrous form. Overall form of glaebule suggests that it developed as a void lining, with quartz grains subsequently emplaced.
4. Colloform features		Absent.
5. Void fills		Small voids unfilled, but centre of glaebule may be considered as a void fill.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	As mentioned above, some Fe-stained calcite in glaebule centre. Also, some poorly deformed crystals of quartz in linear voids.

SAMPLE PROFILE: OKWA2
SAMPLE NUMBER: E

LOCATION: GOBOLOLO CATTLEPOST, OKWA VALLEY
GRID REFERENCE: 22°24'00" S, 20°54'15" E
EXPOSURE TYPE: South bank terrace, 6 m slope at 6°.
HEIGHT (m) ABOVE BASE: 0.20
ASSOCIATED STRATIGRAPHY: Gently sloping terrace level above, valley bed seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	4.5	1. Macro-silica	0
2. Shell	1.5	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	84
Void space (%)	2.5	5. Carbonate void-fill	7

General Description; Massive "M- to F-Fabric" calcrete, with skeletal quartz and shell fragments set in a brown-stained micro-calcite matrix. One partly fragmented gastropod 2.6 mm long. General appearance suggests that a relatively porous framework of (now brown-stained) calcite was deposited, with later deposition of calcite in void spaces.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Many areas of comparatively unstained calcite in voids. Void fills are rarely complete.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	As mentioned above, void fills appear to consist of partial infilling of pores left within a calcite framework. Quartz grains tend to be more concentrated in these void fills suggesting inwashing through a pre-existing framework.

SAMPLE PROFILE: OKWA2
SAMPLE NUMBER: G

LOCATION: GOBOLOLO CATTLEPOST, OKWA VALLEY
GRID REFERENCE: 22°24'00" S, 20°54'15" E
EXPOSURE TYPE: South bank terrace, 6 m slope at 6°.
HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Gently sloping terrace level above, valley bed seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	18	1. Macro-silica	0
2. Shell	3.5	2. Micro-quartz	0
3. Pebble	1	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	70
Void space (%)	4.5	5. Carbonate void-fill	2.5

General Description; "F-Fabric" calcrete with numerous quartz grains (maximum diameter 0.9 mm, mean size 0.3 mm) and common shell fragments (up to 1.75 mm long) set in a microcrystalline calcite matrix.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		One major "glaebule" present (1.5 mm diam.) with the appearance of a pore partly infilled by calcite. Poorly developed concentric laminar pattern present, with a porespace at the centre of the glaebule.
4. Colloform features		Absent.
5. Void fills		No major void fills present, but some pores are partly infilled with microcrystalline calcite which is clearly discernible from the brown-stained matrix material.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Microcrystalline calcite present as incomplete void fills.

SAMPLE PROFILE: OKWA3
SAMPLE NUMBER: A

LOCATION: 12 km West of GHANZI-JWANENG Road, OKWA VALLEY.

GRID REFERENCE: 22°24'00" S, 21°43'50" E
EXPOSURE TYPE: South flank above seasonal pan. From top; 3.5 m slope at 4°, 3.5 m at 9°.

HEIGHT (m) ABOVE BASE: 0.79
ASSOCIATED STRATIGRAPHY: Valley flank above and valley seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	28.5	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	0	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	67.5
Void space (%)	2.5	5. Carbonate void-fill	0.5

General Description; Quite porous "F- to GS-Fabric" calcrete containing skeletal grains of quartz (predominantly), and less commonly shell fragments, silcrete fragments (comprising disordered chalcedony), opaque minerals, albite and augite. These are set in a brown-stained micro-calcite matrix. Very little evidence of pore/void infilling. Maximum grain size 1.7 mm, more commonly ca. 0.2 mm.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Rare.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some minor calcite lining to voids, but not commonplace. Only discernible by slight difference in staining - matrix material is generally more brown-stained.

SAMPLE PROFILE: OKWA3
SAMPLE NUMBER: C

LOCATION: 12 km West of GHANZI-JWANENG Road, OKWA VALLEY.

GRID REFERENCE: 22°24'00" S, 21°43'50" E
EXPOSURE TYPE: South flank above seasonal pan. From top; 3.5 m slope at 4°, 3.5 m at 9°.

HEIGHT (m) ABOVE BASE: 0.65
ASSOCIATED STRATIGRAPHY: Valley flank above and valley seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	14.5	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	0.5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	82.5
Void space (%)	1.5	5. Carbonate void-fill	0.5

General Description; "F-Fabric" calcrete, with skeletal quartz grains, plus occasional feldspar (? andesine) and shell fragments (including one complete gastropod ca. 2.1 mm in length) set in a deep brown-stained micro-calcite matrix. A fairly porous structure, with little evidence of pore infilling by other materials. Most pores are non-linear and not interconnected.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Rare.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some minor lining of pore spaces by microcrystalline calcite, but no completely filled pores present. No major voids present.

SAMPLE PROFILE: OKWA3
SAMPLE NUMBER: E

LOCATION: 12 km West of GHANZI-JWANENG Road, OKWA VALLEY.

GRID REFERENCE: 22°24'00" S, 21°43'50" E
EXPOSURE TYPE: South flank above seasonal pan. From top; 3.5 m slope at 4°, 3.5 m at 9°.

HEIGHT (m) ABOVE BASE: 0.47
ASSOCIATED STRATIGRAPHY: Valley flank above and valley seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	27	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	0.5	3. Silica void-fill	0
4. Other	0	4. Micro-carbonate	65.5
Void space (%)	2	5. Carbonate void-fill	4.5

General Description; "F-Fabric" calcrete, with skeletal quartz grains (plus minor shell fragments, silcrete fragments, plagioclase, opaques and tourmaline) set in a microcrystalline calcite matrix. Relatively porous calcrete, with calcite deposition initially concentrating around individual grains generating a concentric pattern in places. A major semi-circular truncated laminar structure is present, comprising concentric micro-laminated calcite presumably deposited at the edge of a macro-void. Grains "within" the semi-circle are less densely clustered than in the bulk of the section, possibly indicating later infilling.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		One major semi-circular feature at edge of section consisting of micro-laminated calcite.
4. Colloform features		Absent.
5. Void fills		Rare.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some minor partial void infilling by microcrystalline calcite.

SAMPLE PROFILE: OKWA3
SAMPLE NUMBER: G

LOCATION: 12 km West of GHANZI-JWANENG Road, OKWA VALLEY.

GRID REFERENCE: 22°24'00" S, 21°43'50" E
EXPOSURE TYPE: South flank above seasonal pan. From top; 3.5 m slope at 4°, 3.5 m at 9°.

HEIGHT (m) ABOVE BASE: 0.16
ASSOCIATED STRATIGRAPHY: Valley flank above and valley seds below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	27	1. Macro-silica	0
2. Shell	0.5	2. Micro-quartz	0
3. Pebble	0.5	3. Silica void-fill	0
4. Other	0.5	4. Micro-carbonate	67.5
Void space (%)	2	5. Carbonate void-fill	1

General Description; "F- to GS-Fabric" calcrete, with dominantly skeletal well-rounded quartz grains (and minor amounts of shell fragments, ? augite, orthoclase feldspar, opaques and small ? silcrete fragments) in a deeply brown-stained microcrystalline calcite matrix. Relatively porous section, with little evidence for pore infilling. One sub-circular laminated calcite structure present at edge of section, partly truncated.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Possible coating by calcite in the vicinity of some pores.
3. Glaebules		One sub-circular laminated calcite structure almost completely infilled with only slightly brown-stained microcrystalline calcite and some quartz grains.
4. Colloform features		Absent.
5. Void fills		Rare.
	Chalcedony	Absent.
	Microquartz	Absent.
	Calcite	Some lining of voids with microcrystalline calcite.

SAMPLE PROFILE: OKWA4
SAMPLE NUMBER: A
LOCATION: 1.2 km East of TSWAANE Veterinary Post, OKWA VALLEY.
GRID REFERENCE: 22°24'05" S, 21°51'15" E
EXPOSURE TYPE: 2 m vertical outcrop atop 6 m debris slope
HEIGHT (m) ABOVE BASE: 1.75
ASSOCIATED STRATIGRAPHY: Kalahari Sand above, merges with granito rock below.

THIN-SECTION: Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	35.5	1. Macro-silica	0.5
2. Shell	0	2. Micro-quartz	50.5
3. Pebble	0	3. Silica void-fill	5.5
4. Other	0	4. Micro-carbonate	4
Void space (%)	0	5. Carbonate void-fill	4

General Description; Highly complex massive F-Fabric silcrete, comprising skeletal quartz grains (plus minor feldspars, augite and opaques). Matrix consists of microquart almost isotropic cryptocrystalline silica, disordered chalcedony, length-fast chalcedony and some calcite replacing chalcedony (mainly in the vicinity of voids with calcite infills). The main matrix type is disordered chalcedony, with some cryptocrystalline silica, with the latter apparently being deposited first - it sometimes can be seen coating grains which are surrounded by a chalcedony matrix. The calcite void fill commonly se abruptly follows chalcedony but does not appear to replace it. Planar voids are often filled by calcite.

Petrographic Features;

1. Embayments/Fretting		Rare. Some grains show evidence of sligh dissolution.
2. Grain coating		Rare, but some grains have opalline silica chalcedonic overgrowths.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Complex.
	Chalcedony	Various types of void fill. One consists of disordered chalcedony lining, with length-fast chalcedony towards the centre. In sor voids, the l.f. chalcedony followed by megaquartz at centre, often partially infilli void. Some voids have a disordered chal.-l.f.chal.-microcrystalline calcite sequence, with occasional well developed crystals of calcite. Voids are sub-circular as well as planar. Four stages of void fill present, wi one void showing three chalcedony layers with a calcite-filled centre.
	Microquartz	Rare in voids.
	Calcite	Some voids have calcite centres, with varying degrees of crystal size.

SAMPLE PROFILE: OKWA4
SAMPLE NUMBER: C
LOCATION: 1.2 km East of TSWAANE Veterinary Post, OKWA VALLEY.
GRID REFERENCE: 22°24'05" S, 21°51'15" E
EXPOSURE TYPE: 2 m vertical outcrop at top of 6 m debris slope.
HEIGHT (m) ABOVE BASE: 1.25
ASSOCIATED STRATIGRAPHY: Kalahari Sand above, merges with granitoid rock below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	19.5	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	31
3. Pebble	0	3. Silica void-fill	11
4. Other	0	4. Micro-carbonate	37.5
Void space (%)	0	5. Carbonate void-fill	0

General Description; Highly complex F-Fabric massive silcrete comprising skeletal quartz grains, silcrete fragments and minor opaques set in mixed almost isotropic cryptocrystalline silica, disordered chalcedony and calcite matrix. The history of development indicated by the silcrete structure suggests that at least four stages of formation have taken place. The oldest part of the section consists of a brown-stained cryptocrystalline silica matrix. This appears to have been partly replaced by calcite, with the growth of euhedral calcite crystals up to 1 mm long. These crystals commonly have a layer of disordered chalcedony overlying them which forms the majority of the matrix in places, sometimes with megaquartz deposited over this in voids. A common feature of void fills is a final infilling of calcite.

Petrographic Features;

1. Embayments/Fretting		Some embayments.
2. Grain coating		Rare.
3. Glaebules		One glaebule 0.8 mm present consisting of concentric rings of laminated brown-stained calcite.
4. Colloform features		Absent.
5. Void fills		Common and complex.
	Chalcedony	Usually forms outer part of void fill.
	Microquartz	Rare.
	Calcite	Common at centre of void fills.

SAMPLE PROFILE: OKWA4
SAMPLE NUMBER: E

LOCATION: 1.2 km East of TSWAANE Veterinary Post, OKWA VALLEY.
GRID REFERENCE: 22°24'05" S, 21°51'15" E
EXPOSURE TYPE: 2 m vertical outcrop at top of 6 m debris slope.
HEIGHT (m) ABOVE BASE: 0.75
ASSOCIATED STRATIGRAPHY: Kalahari Sand above, merges with granitoid rock below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	14	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	60
3. Pebble	0	3. Silica void-fill	18
4. Other	0	4. Micro-carbonate	1
Void space (%)	1	5. Carbonate void-fill	6

General Description; Complex composite silcrete. Two types of duricrust present - Type 1; an older fractured Fe-rich F- to M-Fabric massive silcrete comprising skeletal quartz grains cemented by an almost isotropic cryptocrystalline silica matrix. Type 2; deposited in sub-parallel planar voids cutting the Fe-rich silcrete is an F-Fabric massive silcrete of skeletal quartz grains in a chalcedony matrix. The matrix of the type 2 silcrete shows definite lamination under p. polarised light, with increasingly well-ordered chalcedony away from grains, although no needle-like chalcedony is present. Some minor calcite present in void fills.

Petrographic Features;

1. Embayments/Fretting		Rare.
2. Grain coating		Some chalcedony coatings, mainly at the junction of the two silcrete types.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Mostly planar void fills separating the two silcrete types.
	Chalcedony	General sequence - disordered chalcedony at planar void margins and increasingly well-ordered chalcedony towards the centre. Some void walls comprise length-fast chalcedony followed abruptly by disordered chalcedony.
	Microquartz	Absent.
	Calcite	Some late stage calcite in one planar void.

SAMPLE PROFILE: OKWA4
SAMPLE NUMBER: G

LOCATION: 1.2 km East of TSWAANE Veterinary Post, OKWA VALLEY.
GRID REFERENCE: 22°24'05" S, 21°51'15" E
EXPOSURE TYPE: 2 m vertical outcrop at top of 6 m debris slope.
HEIGHT (m) ABOVE BASE: 0.00
ASSOCIATED STRATIGRAPHY: Kalahari Sand above, merges with granitoid rock below.

THIN-SECTION:

Grain Count Analysis (200 grains);

Skeletal Grains (%)		Matrix Content (%)	
1. Quartz	6	1. Macro-silica	0
2. Shell	0	2. Micro-quartz	70.5
3. Pebble	0.5	3. Silica void-fill	16
4. Other	0	4. Micro-carbonate	2
Void space (%)	4	5. Carbonate void-fill	1

General Description; Massive F-Fabric silcrete comprising skeletal quartz (plus minor opaques, feldspars) in a dominantly disordered chalcedony matrix with parts of the matrix consisting of brown-stained, almost isotropic cryptocrystalline silica. A number of sub-parallel planar voids cut the section (which was sectioned to provide a vertical cross-section). There is no evidence of grain coating.

Petrographic Features;

1. Embayments/Fretting		Absent.
2. Grain coating		Absent.
3. Glaebules		Absent.
4. Colloform features		Absent.
5. Void fills		Very well-formed planar void fills, with excellent crystal growth.
	Chalcedony	General void fill sequence consists of a thin layer of disordered chalcedony, followed by a layer of crystalline megaquartz, with elongate crystals radiating from the void wall. This megaquartz is often overlain by a layer of coalescing spherulites of length-fast chalcedony showing pseudo-uniaxial extinction crosses, with disordered chalcedony sometimes found at the centre.
	Microquartz	Absent.
	Calcite	Absent.