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8.13 The Fountains of Pretoria

8.13.1 Introduction

The occurrence of groundwater in South Africa is to a very large degree limited to a surficial zone of weathered and fractured hard rock formations. Primary aquifers include narrow strips of alluvium along certain river stretches and to Cenozoic coastal deposits. Coupled with a rainfall that is well below the world average, South Africa is therefore poorly endowed with large springs which are almost totally confined to karst areas.

8.13.2 Background

The principal occurrences of carbonate rocks are the chronostratigraphically equivalent Proterozoic Chuniespoort and Ghaap Groups in the Transvaal and Northern Cape Province (Fig. 8.23). The Chuniespoort dolomitic strata are overlain by a thick succession of clastics of the Pretoria Group and are underlain by a thin band of the Black Reef Quartzite Formation overlying Arhcean granite gneisses south of Pretoria, and other formations elsewhere.

The Chuniespoort Group, which dips northwards in the Pretoria area at about 20°, is over 1 000 m thick (Fig. 8.24). It consists of four formations: chert-free micritic or recrystallized dolomite (bottom and third unit) alternating with chert-rich dolomite composed of alternating beds, bands, and laminae of chert and dolomite (second and top unit).

The chert-free and chert-rich dolomite units weather differently. Whereas deeply penetrating dikes in the former occur only on well spaced discontinuities, dissolution occurs on many more joints and bedding planes in the alternating chert and dolomite sequences. There is a considerable widening of passages below chert ceilings.

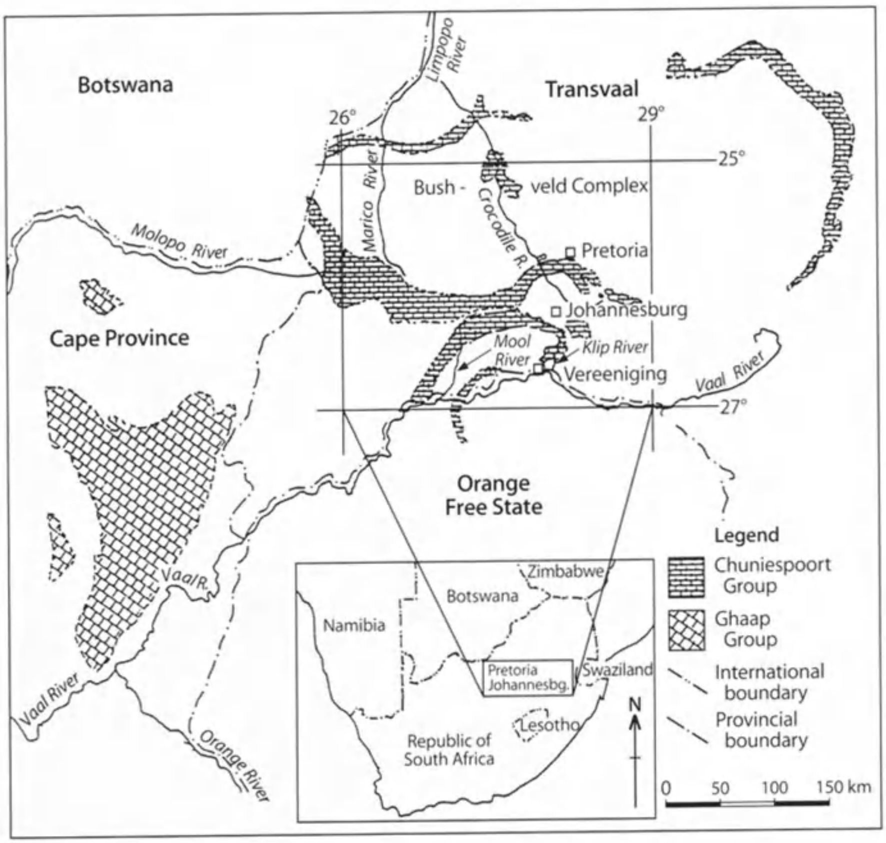


Fig. 8.23.
Location map showing the distribution of carbonate rocks

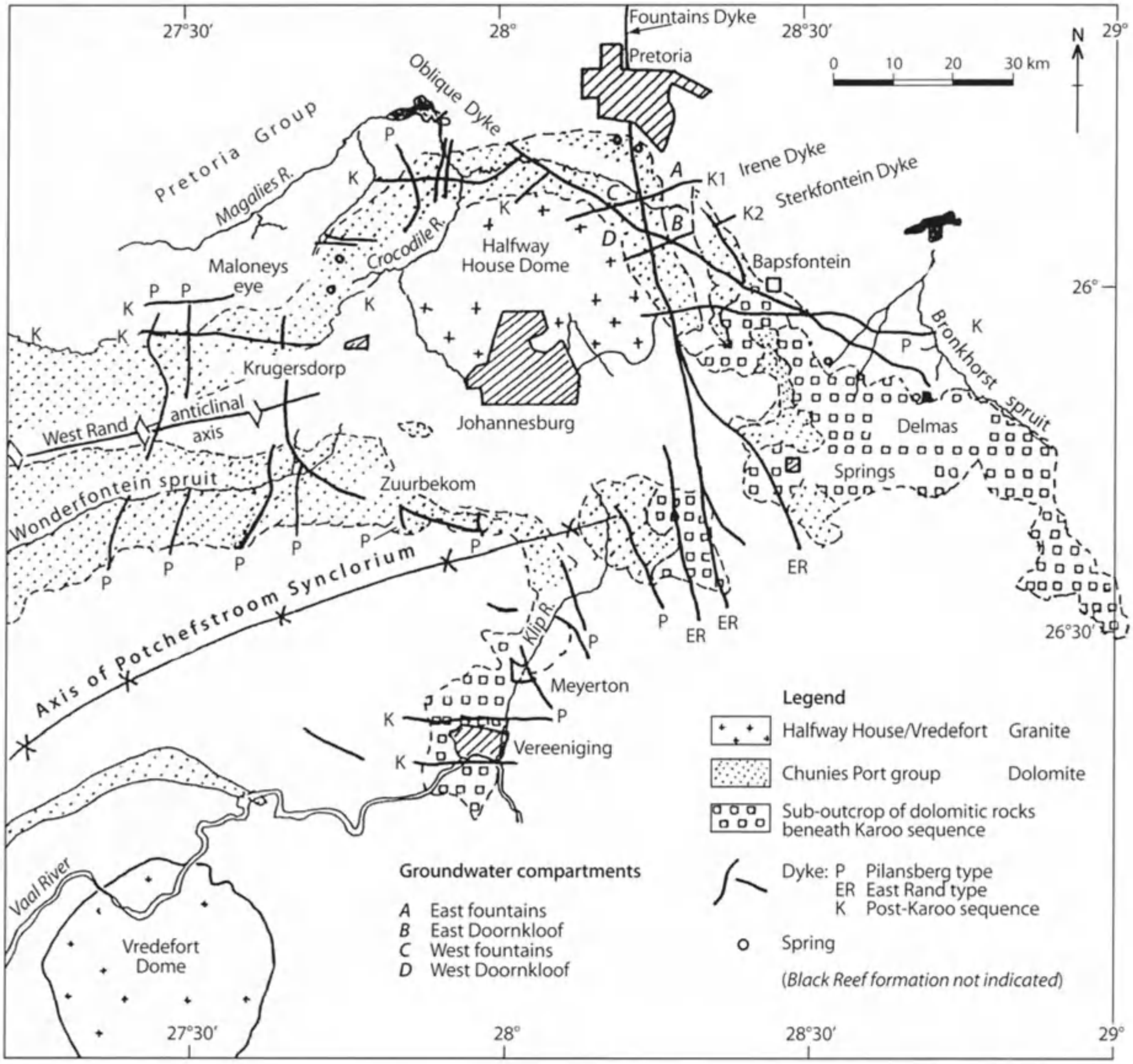


Fig. 8.24. Partitioning of Chuniespoort dolomitic strata by dikes of different ages

The dolomitic aquifers consist of residual dissolution products, chert fragments and wad (a cellular fabric of iron and manganese oxides) and hydroxides, silica and an underlying zone of cavernous to fractured dolomitic rock. The residual products have thicknesses of up to 100 m.

A characteristic feature is the network of dikes of different ages which have intruded the dolomitic strata. The dikes and sills (where present; not shown in figures) have a profound influence on the hydrologic regime by acting as barriers to groundwater movement; thus dividing the strata into separate hydraulic units or compartments. Subsurface flow may, however, occur between compartments at gaps in dikes, where faults displace them and where weathered and fractured dike rock extends to below the groundwater level. Most springs issue on or near contacts within dikes in the underlying Black Reef quartzite or the overlying Pretoria Group clastics. Flows range from less than 0.001 to about 3 m^3/s.

8.13.3 The Pretoria Fountains

Although by no means the largest, the two springs known as "The Fountains" have been selected as most noteworthy for South Africa. The city of Pretoria, the administrative capital of the Republic of South Africa, owes its birth in 1855 to these springs, which form the headwaters of the Apies River.

Initially, the flow of the springs was diverted by means of a weir into furrows running down the sidewalks. This crude distribution system was superseded by pipelines in 1890. By 1928 the discharge from The Fountains could no longer meet the city's requirements, and spring and surface water had to be developed further away from the city, first from Rietvlei Dam on the Hennops River and, subsequently, after the Second World War, from the Vaal River. In 1992, The Fountains supplied 7.3% of the city's average requirements.

8.13.4 Hydrogeological Setting

The hydrogeologic setting is illustrated by a simplified map (Fig. 8.25) and a north-south section of the piezometric surface (Fig. 8.26) east of the Fountains dike. A section west of the dike is very similar. The compartmenting role of the Irene, Sterkfontein, Oblique, and

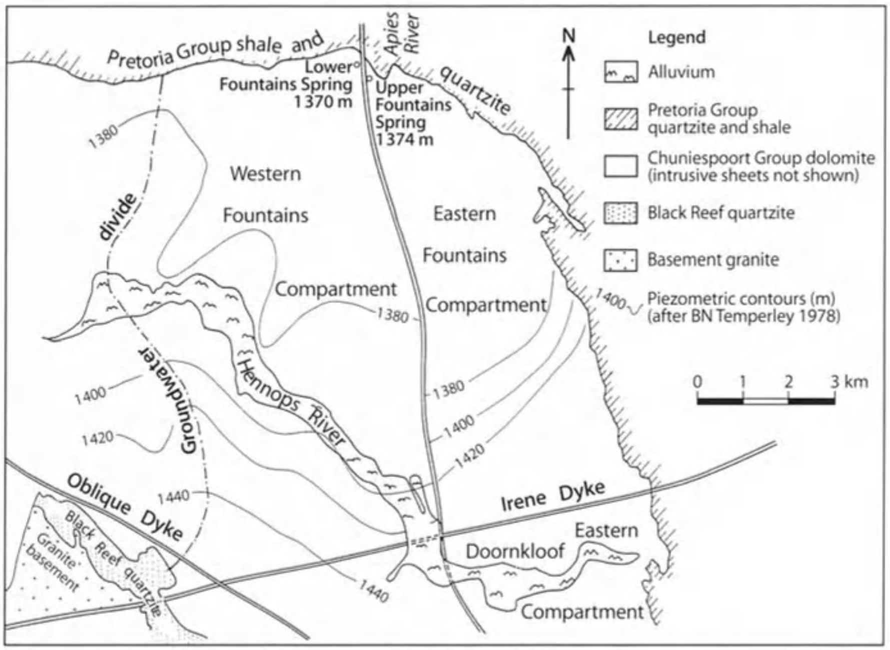


Fig. 8.25. Simplified hydrogeological map of the Pretoria Fountains

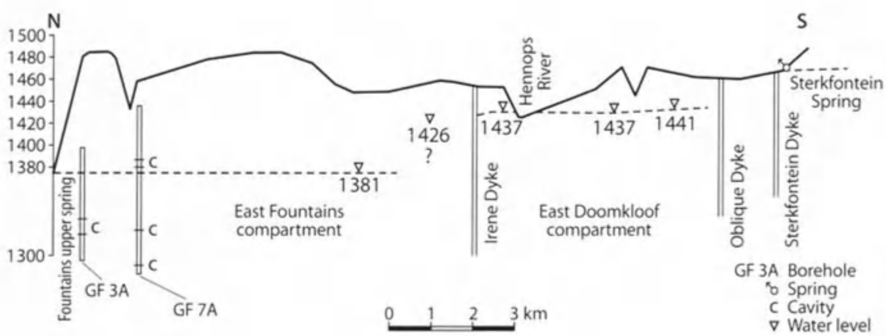
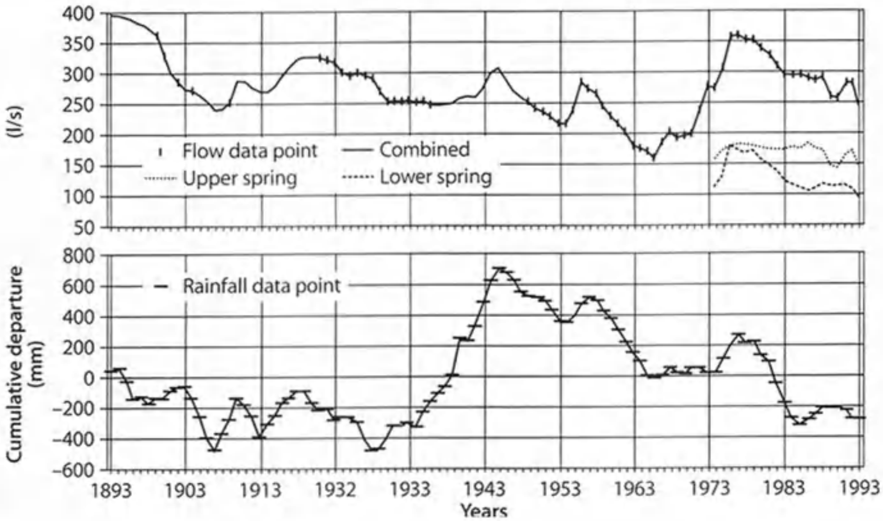


Fig. 8.26. Schematic piezometric section *A* east of The Fountains dike (adapted from Robertson and Kirsten 1985)

Fig. 8.27.
Flow rates and cumulative departure of mean seasonal rainfall



Fountains dikes should be noted as well as the stepped and low hydraulic gradients that are typical of the Transvaal karst. Note also that the east and west Fountains compartments straddle catchments of the Apies and Hennops Rivers.

The upper (eastern) and lower (western) springs (piezometric difference about 4 m) are approximately 500 m apart on either side of the impervious Fountains dike. They are about 200 m south of the line of junction between the overlying Pretoria Group shale and quartzite and the dolomitic strata. In this area the strata are cut by many dip and oblique faults and The Fountains dike follows one of them.

8.13.5 Flow Characteristics

Although the flows from the springs have been gaged separately over the past 24 years, data available for past years are for combined flows only. In Fig. 8.27 graphs of the yearly mean combined flow rate in l/s and the smoothed (moving 3-year average) cumulative departure from the long-term mean rainfall (of the hydrologic year October to September) are shown. The mean summer rainfall is about 675 mm. In general, both graphs have the same pattern. The fact that recharge and spring flow depend on other factors besides total seasonal rainfall is clearly demonstrated by differing spring responses to cumulative departures from mean rainfall. Note that the flow has been interpolated for the period 1892 to 1908 from some widely separated discharge figures, the accuracy of which may be questioned. The flow has been extrapolated for the periods 1908 to 1919 and 1935 to 1948 for which no data are available. Over the past century the combined flow has fluctuated between 160 and 197 l/s. The dissimilar behavior of discharge between 1969 and 1992 of the upper and lower springs is also noteworthy.

8.13.6 Hydrochemistry

Analysis of cuttings from drill holes penetrating the different stratigraphic horizons has shown that in more than 80% of the samples, the CaO : MgO ratio exceeds the theoretical value for pure dolomite, i.e., 1 : 0.72 by weight. The dolomitic strata are calcium rich (Vegter and Foster 1992).

It has been recognized by Bond (1946) that the CaO : MgO ratio in water from dolomitic springs in the Transvaal is lower than in the dolomite, in spite of being calcium rich. This means that between the dissolution process by rain percolating through the dolomite and its reappearance at the springs, part of the calcium is deposited as calcite and aragonite in caves above the water level (Martini 1973). The variation in chemical composition with time is illustrated in Table 8.10. The spring water is essentially a calcium magnesium bicarbonate water.

Table 8.10. Variation in chemical composition of dolomitic springs in the Transvaal

	Dates of samples				
	Feb–April 1937	Jan 1940	Aug 1980	July–Dec 1985	July–Oct 1990
Total dissolved solids (mg/l)	209	210	272	312	260
Total alkalinity as $CaCO_3$ (mg/l)	198	192		199	200
Total hardness as $CaCO_3$ (mg/l)	200	204		218	222
Ca	40.3	36.5	34.5	41.4	43.2
Mg	23.7	27.3	26.1	32.7	31.0
Na	5.9		7.9		
Cl	1.7	1.7	13.9	25.1	19.5
SO_4	(3.0)?	0.05	4.5	6.9	7.8
NO_3		0.04	1.9	10.6	8.4
PO_4			0.03	0.0	0.40
SiO_2	12.8	70.2	31.7		
CaO : MgO ratio	1:0.70	1:0.88	1:0.78	1:0.90	1:0.90
Reference	Cilliers (1953)	Bond (1946)	Water Affairs Laboratory	Municipal laboratory	Municipal laboratory

Composition of combined flow except for the Jan 1940 analysis which is of one of the springs.

8.13.7 Remarks

Over the past 100 years the land use of the groundwater catchment areas of the upper and lower springs has changed from mixed farming to largely urban. This change has occurred at an accelerating pace from about 1950 to present. Because of the complicating effect of long-term fluctuations, it is uncertain whether spring flow is gradually declining. As far as is known, little, if any, groundwater is being abstracted from boreholes. The effect of human activities is best illustrated by the increase in chloride, sulphate, nitrate and phosphate. Judging by the ratios 1 : 82 and 1 : 100 between mean volume groundwater recharged annually and volume of water in storage for two compartments on the Far West Rand (Vegter and Foster 1992), the full effect of ongoing groundwater pollution will probably be realized only after a lengthy period of time.

Acknowledgements

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