

## Table of contents

<b>1</b>	<b>INTRODUCTION.....</b>	<b>1</b>
1.1	INTRODUCTION.....	1
1.2	PREVIOUS WORK.....	4
1.3	UNRESOLVED PROBLEMS (PROBLEM STATEMENT) .....	8
1.4	WORK PLAN.....	11
1.5	REFERENCES.....	13
<b>2</b>	<b>STRATIGRAPHY OF THE KEIS SUPERGROUP.....</b>	<b>15</b>
2.1	INTRODUCTION.....	15
2.2	STRUCTURE .....	16
2.3	REVISED STRATIGRAPHIC SUBDIVISION.....	17
2.4	LITHOSTRATIGRAPHY .....	27
2.4.1	LOCATION OF STRATIGRAPHIC PROFILES .....	27
2.4.2	TRANSVAAL SUPERGROUP .....	27
2.4.2.1	VOëLWATER SUBGROUP.....	27
2.4.2.1.1	<i>Beaumont Formation</i> .....	27
2.4.2.2	ELIM GROUP .....	28
2.4.2.2.1	<i>Mapedi Formation</i> .....	28
2.4.2.2.2	<i>Lucknow Formation</i> .....	28
2.4.3	KEIS SUPERGROUP.....	29
2.4.3.1	Olifantshoek Group.....	29
2.4.3.1.1	<i>Neylan Formation</i> .....	29
2.4.3.1.2	<i>Hartley Formation</i> .....	33
2.4.3.1.3	<i>Volop Formation</i> .....	34
2.4.3.1.4	<i>Top Dog Formation</i> .....	41
2.4.3.2	Grobbershoop Group .....	41
2.4.3.2.1	<i>Faanshoek Formation</i> .....	42
2.4.3.2.2	<i>Faansgeluk Formation</i> .....	44
2.4.3.2.3	<i>Maraisdraai Formation</i> .....	45
2.4.3.2.4	<i>Vuilnek Formation</i> .....	46
2.4.3.2.5	<i>Opwag Formation</i> .....	50
2.4.3.2.6	<i>Skurweberg Formation</i> .....	55
2.4.3.3	Wilgenhoutsdrif Group .....	59
2.4.3.3.1	<i>Grootdrink Formation</i> .....	60
2.4.3.3.2	<i>Zonderhuis Formation</i> .....	60
2.4.3.3.3	<i>Leerkrans Formation</i> .....	63
<b>2.5</b>	<b>THE DABEP FAULT REVISITED.....</b>	<b>64</b>

2.6	<b>SUMMARY AND DISCUSSION OF STRATIGRAPHIC AND SEDIMENTOLOGICAL DEVELOPMENT</b> .....	67
2.7	<b>TECTONO SEDIMENTARY MODEL</b> .....	72
2.8	<b>CONCLUSIONS</b> .....	75
2.9	<b>REFERENCES</b> .....	76
3	<b><i>CONTRASTING PROVENANCE OF SEDIMENTARY ROCKS OF THE KHEIS AND KAKAMAS TERRANES ADJOINING THE NAMAQUA FRONT</i></b> .....	80
3.1	<b>INTRODUCTION</b> .....	80
3.2	<b>GEOLOGICAL OVERVIEW</b> .....	80
3.2.1	KEIS SUPERGROUP .....	81
3.2.2	AREACHAP GROUP .....	84
3.2.3	KAKAMAS TERRANE.....	85
3.2.4	KORAS GROUP .....	86
3.2.5	NAMAQUA FRONT .....	87
3.3	<b>PETROGRAPHY OF THE SEDIMENTARY ROCKS OF THE KHEIS AND KAKAMAS TERRANES</b> .....	87
3.3.1	LUCKNOW FORMATION .....	88
3.3.2	KEIS SUPERGROUP.....	89
3.3.2.1	Olifantshoek Group.....	89
3.3.2.2	Groblershoop Group .....	96
3.3.2.3	Wilgenhoutsdrif Group .....	98
3.3.3	GOEDEHOOP FORMATION, KORANNALAND GROUP.....	101
3.4	<b>HEAVY MINERAL POPULATIONS</b> .....	102
3.4.1	METHOD AND CLASSIFICATION .....	102
3.4.2	OLIFANTSHOEK GROUP .....	103
3.4.3	GROBLERSHOOP GROUP .....	107
3.4.4	WILGENHOUTSDRIF GROUP.....	109
3.4.5	GOEDEHOOP FORMATION, KORANNALAND GROUP.....	109
3.5	<b>DETRITAL ZIRCON AGE DETERMINATIONS</b> .....	109
3.5.1	INTRODUCTION .....	109
3.5.2	LUCKNOW FORMATION of the TRANSVAAL SUPERGROUP.....	110
3.5.3	OLIFANTSHOEK GROUP .....	112
3.5.4	GROBLERSHOOP GROUP .....	122
3.5.5	WILGENHOUTSDRIF GROUP.....	126
3.5.6	KORANNALAND GROUP .....	131
3.5.6.1	Goedehoop Formation .....	131

3.5.6.2	Sandputs Formation .....	135
3.5.6.3	Collinskop Formation .....	137
3.5.7	SPRIGG FORMATION .....	140
<b>3.6</b>	<b>CRYSTALLISATION AGE OF THE KOKERBERG GNEISS .....</b>	<b>143</b>
<b>3.7</b>	<b>DISCUSSION .....</b>	<b>146</b>
3.7.1	COMPOSITION OF SOURCE ROCKS .....	146
3.7.1.1	Evidence from petrographic studies .....	146
3.7.1.2	Evidence from heavy mineral populations .....	146
3.7.1.2.1	<i>Introduction .....</i>	<i>146</i>
3.7.1.2.2	<i>Origin of the opaque hematite-ilmenite and pyrite population .....</i>	<i>147</i>
3.7.1.2.3	<i>Mica, glauconite and rutile.....</i>	<i>148</i>
3.7.1.2.4	<i>Heavy mineral assemblages as indicators of plate tectonic environments.....</i>	<i>149</i>
3.7.1.2.5	<i>Zircon composition and texture.....</i>	<i>150</i>
3.7.2	POSSIBLE SOURCES FOR DETRITAL ZIRCON AGE POPULATIONS .....	153
3.7.2.1	Keis Supergroup versus Korannaland Group age populations .....	153
3.7.2.2	Possible source areas for the Keis Supergroup .....	157
3.7.2.3	Possible source areas for the Korannaland Group .....	161
3.7.3	STRATIGRAPHIC VARIATIONS IN DETRITAL ZIRCON AGE POPULATIONS .....	163
3.7.3.1	Lucknow Formation of the Elim Group of the Transvaal Supergroup.....	163
3.7.3.2	Keis Supergroup .....	163
3.7.3.3	Korannaland Group.....	167
3.7.3.4	Sprigg Formation .....	168
<b>3.8</b>	<b>TECTONIC SIGNIFICANCE OF PROVENANCE DATA.....</b>	<b>169</b>
<b>3.9</b>	<b>REFERENCES.....</b>	<b>172</b>
<b>4</b>	<b><sup>40</sup>Ar/<sup>39</sup>Ar GEOCHRONOLOGY OF SELECTED SAMPLES IN THE KHEIS- AND KAKAMAS TERRANES.....</b>	<b>179</b>
<b>4.1</b>	<b>INTRODUCTION.....</b>	<b>179</b>
<b>4.2</b>	<b>SAMPLE LOCATIONS .....</b>	<b>179</b>
4.2.1	GOEDEHOOP FORMATION of THE KORANNALAND GROUP .....	179
4.2.2	GROBLERSHOOP GROUP OF THE KEIS SUPERGROUP .....	181
<b>4.3</b>	<b><sup>40</sup>Ar/<sup>39</sup>Ar GEOCHRONOLOGY .....</b>	<b>183</b>
<b>4.4</b>	<b>DISCUSSION .....</b>	<b>187</b>
<b>4.5</b>	<b>CONCLUSIONS .....</b>	<b>188</b>
<b>4.6</b>	<b>REFERENCES.....</b>	<b>190</b>
<b>5</b>	<b>PLATE TECTONIC MODEL .....</b>	<b>191</b>

<b>5.1</b>	<b>INTRODUCTION.....</b>	<b>191</b>
<b>5.2</b>	<b>NEW FINDINGS OF THIS STUDY THAT NEEDS TO BE EXPLAINED IN A PLATE TECTONIC MODEL .....</b>	<b>196</b>
<b>5.3</b>	<b>BROAD TECTONIC FRAMEWORK.....</b>	<b>198</b>
<b>5.4</b>	<b>SUMMARY OF MAJOR FEATURES OF DIFFERENT TERRANES AND ROCK UNITS .....</b>	<b>201</b>
5.4.1	KAAPVAAL CRATON.....	201
5.4.2	ZIMBABWE CRATON.....	202
5.4.3	LIMPOPO AND MAGONDI BELTS.....	205
5.4.4	KEIS SUPERGROUP.....	205
5.4.4.1	Olifantshoek Group.....	205
5.4.4.2	Grobbershoop Group.....	209
5.4.4.3	Wilgenhoutsdrif Group.....	210
5.4.5	AREACHAP GROUP.....	212
5.4.6	KGALAGADI TERRANE.....	213
5.4.7	RICHTERSVELD AND KAKAMAS TERRANES.....	215
5.4.8	KEIMMOES SUITE.....	218
5.4.9	KORAS GROUP.....	219
5.4.10	SPRIGG FORMATION.....	221
5.4.11	OTHER CONSIDERATIONS.....	221
<b>5.5</b>	<b>PLATE TECTONIC MODEL.....</b>	<b>222</b>
5.5.1	KEIS PASSIVE MARGIN BASIN AND PROVENANCE.....	222
5.5.2	COLLISIONAL TECTONICS.....	223
<b>5.6</b>	<b>CONCLUSIONS.....</b>	<b>228</b>
<b>5.7</b>	<b>REFERENCES.....</b>	<b>230</b>
<b>6</b>	<b>CONCLUSIONS.....</b>	<b>236</b>
<b>A</b>	<b><i>Appendix A: THE KAAPVAAL-KHEIS-NAMAQUA PROBLEM: A LITERATURE STUDY INTO 130 YEARS OF CONTINUING RESEARCH.....</i></b>	<b>242</b>
<b>A.1</b>	<b>INTRODUCTION.....</b>	<b>242</b>
<b>A.2</b>	<b>INITIAL DEVELOPMENT LITHOSTRATIGRAPHIC CLASSIFICATIONS.....</b>	<b>243</b>
A.2.1	PERIOD 1874 TO 1973.....	243
A.2.2	PERIOD 1974 TO 1980.....	250
A.2.3	PERIOD 1980 TO 1999.....	260
A.2.3.1	Wilgenhoutsdrif Formation.....	260
A.2.3.2	Kaaien Group.....	266
A.2.3.3	Marydale Group.....	268

A.2.3.4	Olifantshoek Sequence .....	268
A.2.3.5	Keimoes Suite .....	273
A.2.3.6	Areachap Group .....	274
A.2.3.7	Tectonic Domains .....	275
A.2.3.8	Koras Group .....	279
<b>A.3</b>	<b>A NEW LITHOLOGICAL SUBDIVISION FOR THE KHEIS TECTONIC PROVINCE (1999).....</b>	<b>282</b>
A.3.1	OLIFANTSHOEK SUPERGROUP .....	283
A.3.2	BRULPAN GROUP .....	284
A.3.3	VAALKOPPIES GROUP.....	288
A.3.4	WILGENHOUTSDRIF GROUP.....	289
<b>A.4</b>	<b>STRUCTURAL FEATURES AND DEFORMATIONAL HISTORY .....</b>	<b>292</b>
A.4.1	STRUCTURAL CONTROL ON KORAS DEPOSITION .....	292
A.4.2	STRUCTURAL EVOLUTION OF THE TRANSITIONAL ZONE BETWEEN THE KAAPVAAL CRATON AND THE NAMAQUA MOBILE BELT .....	293
A.4.3	LINEAMENTS AND FAULTS OF THE KHEIS BELT .....	295
A.4.4	TECTONIC TERRANES AND PROVINCES IN THE UPINGTON AREA.....	297
A.4.5	DEFORMATION ALONG THE EASTERN BOUNDARY OF THE NAMAQUA PROVINCE.....	304
A.4.6	POLYPHASE DEFORMATION OF THE KHEIS TECTONIC PROVINCE .....	306
A.4.7	THE DABEP FAULT AS A TERRANE BOUNDARY.....	307
<b>A.5</b>	<b>THE METAMORPHISM OF THE SUCCESSIONS OF THE WESTERN MARGIN OF THE KAAPVAAL CRATON, KHEIS- AND NAMAQUA-NATAL MOBILE BELT. ....</b>	<b>312</b>
A.5.1	METAMORPHISM OF THE AREA BETWEEN WILGENHOUTSDRIF AND KAKAMAS.....	312
A.5.2	METAMORPHISM OF THE KHEIS TECTONIC PROVINCE .....	313
<b>A.6</b>	<b>MODELS FOR THE SEDIMENTOLOGICAL AND TECTONIC DEVELOPMENT OF THE SUCCESSIONS ON THE WESTERN MARGIN OF THE KAAPVAAL CRATON, KHEIS- AND NAMAQUA-NATAL MOBILE BELT. ....</b>	<b>316</b>
A.6.1	OLIFANTSHOEK SEQUENCE .....	316
A.6.1.1	Deposition of the Volop Group of the Olifantshoek Sequence .....	316
A.6.1.2	Rifting and the formation of the Olifantshoek sequence .....	317
A.6.2	WILGENHOUTSDRIFT GROUP .....	320
A.6.2.1	The deposition of the Wilgenhoutsdrif Formation .....	320

A.6.2.2	Tectonic events giving rise to the formation of the Wilgenhoutsdrif Formation.....	321
A.6.3	AREACHAP GROUP .....	322
A.6.3.1	Tectonic model for the development of the Areachap Group and the Keimoes Suite .....	322
A.6.3.2	Two-stage model for the development of the Jannelsepan Formation.....	323
A.6.4	KHEIS TECTONIC PROVINCE .....	324
A.6.4.1	Depositional environment of the Kheis Tectonic Province.....	324
A.6.4.2	Tectonic evolution of the Kheis Tectonic Province.....	325
A.6.5	NAMAQUA MOBILE BELT .....	328
A.6.5.1	The tectonic development of the Namaqua Mobile Belt and its foreland .....	328
A.6.5.2	A geodynamic model for the northeastern boundary of the Namaqua Province.....	330
A.6.5.3	Rifting model for the north-eastern boundary of the Namaqua Province .....	331
A.6.5.4	Evolution of the lavas of the Koras Group and the Namaqualand granites.....	333
A.6.5.5	Tectonic model for the Namaqua Province .....	334
A.6.5.6	Development of the Namaqua Province .....	336
A.6.5.7	Evolution of the Namaqua-Natal Province in terms of a complete Wilson Cycle.....	338
A.6.5.8	Kinematic evolution of Namaqua-Natal-Dronning Maud Land.....	339
A.6.6	THE KORAS GROUP.....	341
A.6.6.1	Deposition of the Koras Formation .....	341
A.6.6.2	The deposition of the Koras Group.....	342
A.6.6.3	Deposition of the Koras Group in three domains .....	342
A.6.6.4	Similarities between the Wilgenhoutsdrif- and Koras Groups .....	343
<b>A.7</b>	<b>DISCUSSION .....</b>	<b>345</b>
<b>A.8</b>	<b>REFERENCES.....</b>	<b>347</b>
<b>B</b>	<b><i>Appendix B: PETROGRAPHIC DESCRIPTIONS OF SEDIMENTARY ROCKS FROM THE KEIS SUPERGROUP AND THE KORANNALAND GROUP.....</i></b>	<b>353</b>
<b>C</b>	<b><i>Appendix C: REINTERPRETED STRATIGRAPHIC MAP OF THE KHEIS TERRANE AND NAMAQUA PROVINCE IN THE NORTHERN CAPE PROVINCE, SOUTH AFRICA.....</i></b>	<b>400</b>
<b>D</b>	<b><i>Appendix D: REINTERPRETED LITHOLOGICAL MAP OF THE KHEIS TERRANE AND NAMAQUA PROVINCE IN THE NORTHERN CAPE PROVINCE, SOUTH AFRICA.....</i></b>	<b>402</b>