Magmatic–hydrothermal breccia dykes and hydrothermal alteration in the McHale Granodiorite, Halls Creek Orogen: a possible porphyry system

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Abstract

The 1827 ± 3 Ma McHale Granodiorite is exposed to the east of the Halls Creek Fault, approximately 10 km southeast of Warmun (Turkey Creek). Two main granitoid phases are extensively altered and cut by magmatic–hydrothermal breccia dykes. Alteration styles include propylitic and potassic alteration, sericitization, silicification and argillic alteration. Magmatic–hydrothermal breccia dykes are formed at shallow crustal levels by the violent release of a volatile phase from a subjacent magma chamber. The dykes and the documented styles of alteration in the McHale Granodiorite are found typically in mineralized porphyry-copper and epithermal environments. The rocks described in this paper may represent a fault-displaced portion of a larger porphyry/epithermal system that also hosts the Angelo copper deposit, south of Halls Creek.

KEYWORDS: Palaeoproterozoic, Kimberley Province, Halls Creek Orogen, McHale Granodiorite, magmatic–hydrothermal breccia dykes, hydrothermal alteration, mineralization

During 1995, the Geological Survey of Western Australia conducted a field and literature (including WAMEX) survey to document occurrences of economically significant minerals in the Halls Creek Orogen and adjoining areas of the Kimberley region. This project follows up a regional geological mapping program carried out in conjunction with the Australian Geological Survey Organisation, under the National Geoscience Mapping Accord.

A large area of hydrothermally altered granite cut by magmatic–hydrothermal breccia dykes was identified approximately 10 km southeast of Warnum (Turkey Creek). This area (Fig. 1) contains several minor copper occurrences and the geological features described in this paper suggest the potential for porphyry or epithermal precious and base metal mineralization. Other occurrences of epithermal mineralization, west and northwest of Halls Creek, have been described by Pirajno et al. (1994).

Regional geology

The area described lies immediately east of the Halls Creek Fault and lies within the central zone of the Lamboo Complex of the Halls Creek Orogen (Tyler et al., 1995). The area is underlain mainly by McHale Granodiorite which forms part of the Sally Downs Batholith (Sheppard et al., 1995). McHale Granodiorite has been dated by SHRIMP at 1827 ± 3 Ma (Page, R. W., 1994, pers. comm.) and is unconformably overlain by the Palaeoproterozoic Red Rock Formation. Younger, Meso- to Neoproterozoic sedimentary rocks (Helicopter Siltstone and Duerdin Group) to the east are in fault contact with McHale Granodiorite (Figs 1, 2). Farther south, between the Halls Creek Fault and the Osmond Fault, McHale Granodiorite intrudes a sequence of metasedimentary rocks that may be equivalent to the c. 1840 Ma Koongie Park Formation, exposed near Halls Creek (Tyler et al., in prep.). These two areas will be referred to as the northern, and southern occurrences, respectively, of the McHale Granodiorite.

McHale Granodiorite

Although termed McHale Granodiorite by Dow and Gemuts (1969), most samples collected during this study range from diorite to granodiorite, with leucocratic tonalite being the most common. The undeformed to weakly deformed nature of the McHale Granodiorite, in conjunction with the widespread alteration and other evidence for hydrothermal activity, contrasts with the prominent exposures of the coeval Mabel Downs Tonalite west of the Halls Creek Fault (Fig. 1). These outcrops of Mabel Downs Tonalite are locally strongly deformed but display little evidence of hydrothermal activity.

Southern occurrences of McHale Granodiorite

The least-altered outcrops of McHale Granodiorite lie in the Osmond Valley, between the Halls

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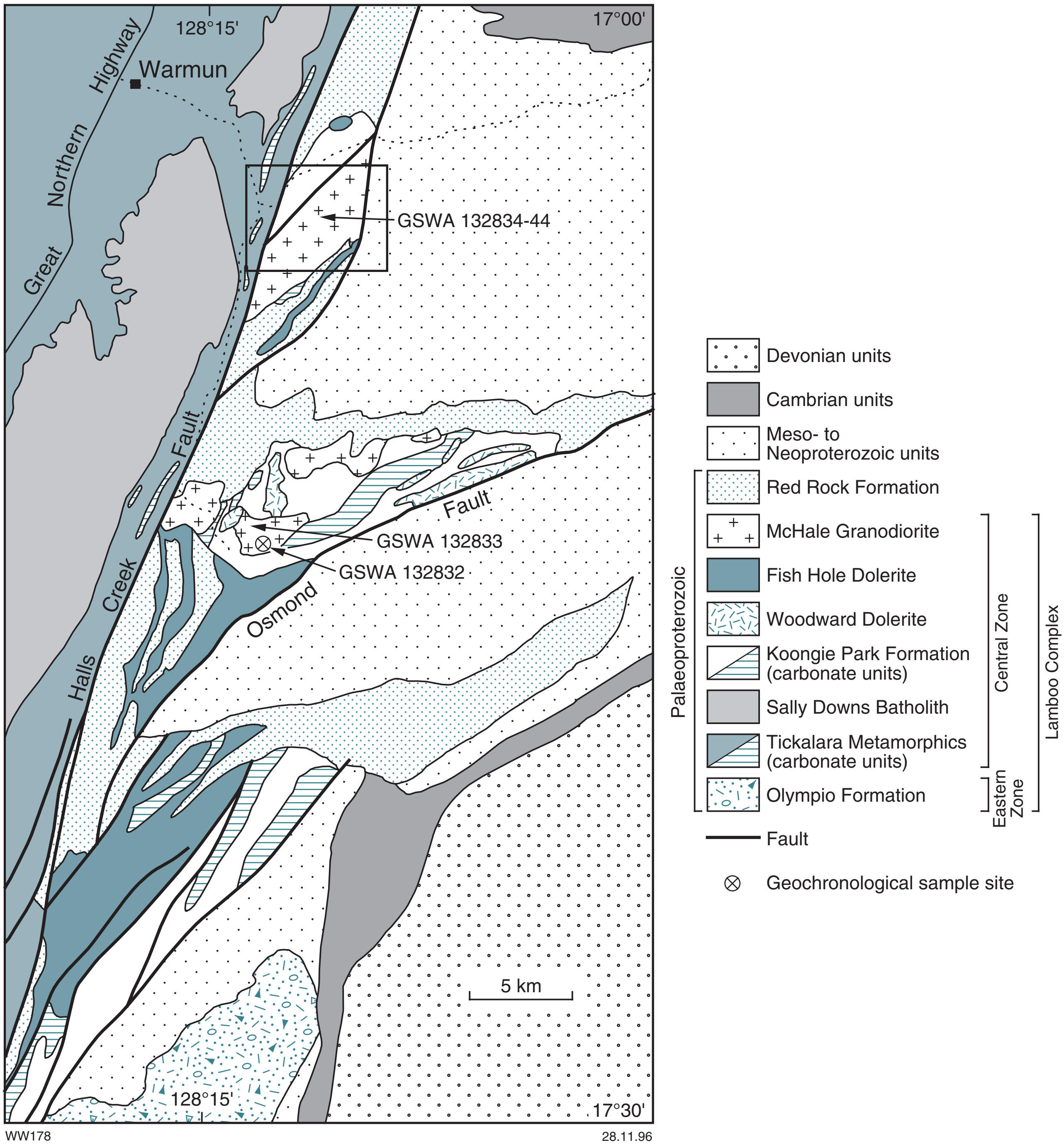


Figure 1. Regional geology of a part of the Halls Creek Orogen, showing distribution of the McHale Granodiorite and location of Figure 2

Creek Fault and the Osmond Fault (Fig. 1). Sample GSWA 132832 is a weakly foliated, equigranular, coarse-grained (2–4 mm) hornblende–biotite tonalite with about 8% biotite and 2% amphibole. Plagioclase (low-Ca andesine) is the dominant feldspar, with K-feldspar minor to absent. GSWA 132833 is texturally similar to GSWA 132832 but is less deformed and more intensely altered. Amphibole or pseudomorphs of amphibole were not recognized. Biotite is pseudomorphed by chlorite with minor neoblastic muscovite locally developed. Approximately 15% (?secondary) microcline occurs as fine-grained, granoblastic aggregates along grain boundaries between plagioclase and quartz.

The northern occurrence of McHale Granodiorite

The northern occurrence of the McHale Granodiorite is texturally similar to the southern occurrences

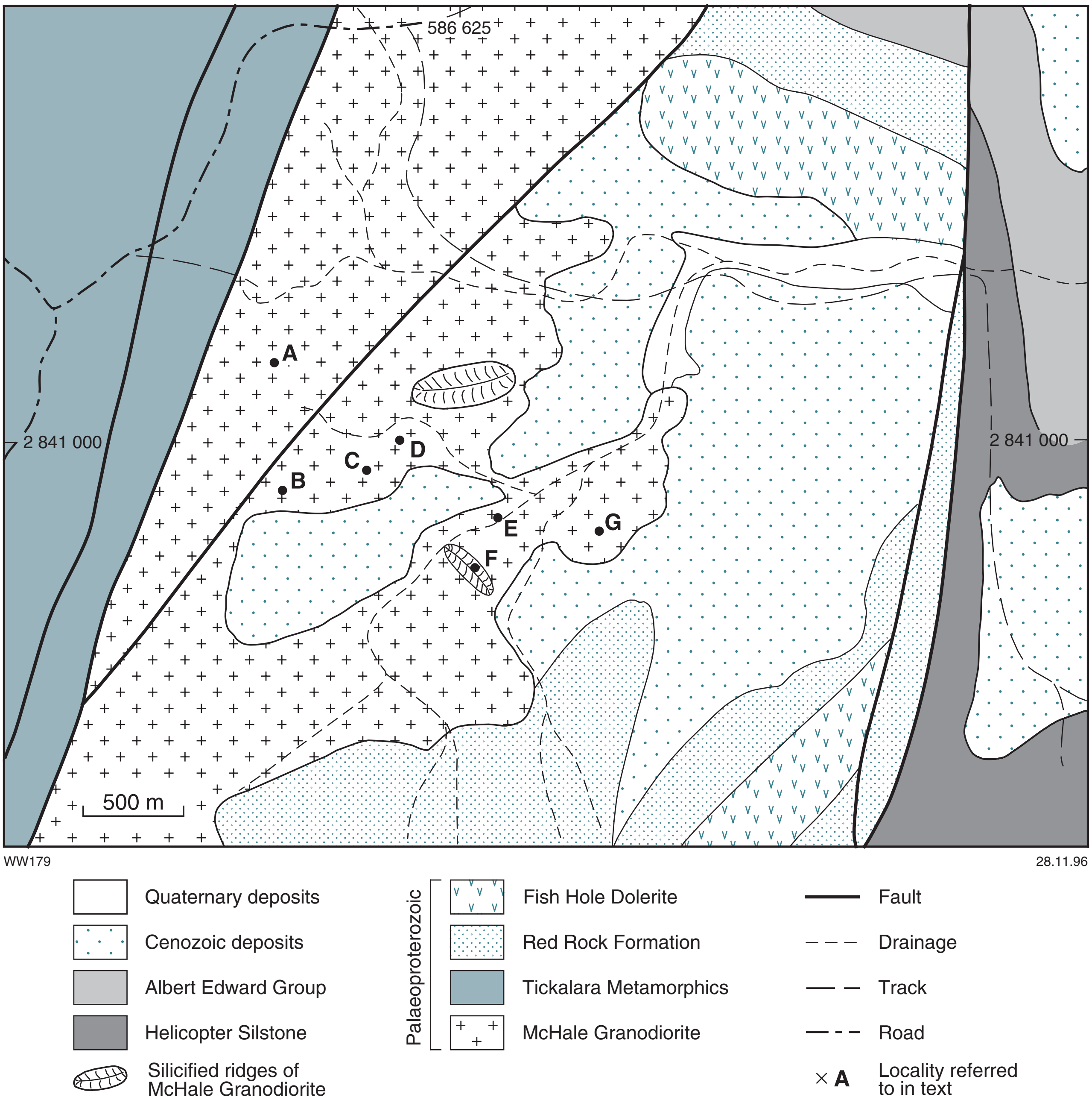


Figure 2. Geology of the Halls Creek Orogen, southeast of Warmun (Turkey Creek), showing localities referred to in the text

but is much more extensively and intensely altered and is cut by swarms of magmatic–hydrothermal breccia dykes. A pink to deep red colour reflects widespread to pervasive hematitization of the granitoid. The area is characterized by sparse, low, rubbly outcrop although there are two prominent ridges of silicified granodiorite (Fig. 2). Discontinuous pods, lenses and dykes of pegmatitic granite with bright pink feldspar occur within the granitoid, and at locality G appear to pass along strike into a magmatic–hydrothermal breccia dyke. Larger (1–2 m wide) veins of carbonate containing fragments of magmatic–hydrothermal breccia dykes are present at locality G. Weathered granitoid outcrops in the creek crossing at locality E (Fig. 2) are cut by numerous quartz and carbonate veins and veinlets, which are locally limonitic (?after pyrite or ankerite), and a magmatic–hydrothermal breccia dyke with well-rounded ('milled') clasts. The least-altered granitoid sample (GSWA 132834, from locality G, Fig. 2) is an equigranular, coarse-grained (2–3 mm) biotite tonalite with about 5% (?primary) K-feldspar and 10% chlorite and muscovite pseudomorphs after biotite. Low-Ca andesine is extensively sericitized and the rock is cut by several thin veinlets of quartz, carbonate and K-feldspar (?adularia). The two ridges shown in Figure 2 are composed of extensively fractured and altered granitoid, cut by several dykes of magmatic–hydrothermal breccia and quartz–feldspar porphyry. Sample GSWA 132835 (from locality F, Fig. 2) is texturally similar to GSWA 132834 but ferromagnesian minerals have been completely destroyed. The feldspathic component of the rock is pseudomorphed by cryptocrystalline quartz and clay minerals (probably interlayered illite–kaolin; Fig. 3G). Domains dominated by clay minerals are accompanied by fine-grained disseminated anatase (Fig. 3H). Fine-grained disseminations of dusty hematite are ubiquitous.

The relatively leucocratic granodiorite or tonalite described above occurs with irregular dykes and plugs of more melanocratic granitoids at localities A, B and C (Fig. 2). Relative-timing relationships are suggested by local exposures of leucocratic dykes and pegmatite cutting more melanocratic phases. The relatively mafic intrusive phase (GSWA 132844) is mainly coarse-grained (1–2 mm), equigranular diorite with about 40% amphibole. Although only weakly deformed, the diorite is pervasively altered with potassic alteration overprinting an earlier phyllic or propylitic stage. Plagioclase is extensively sericitized whereas amphibole is pseudomorphed by fine-grained chlorite, calcite, quartz and finely divided titanite. There is also 5–10% secondary quartz along grain boundaries and as inclusions in amphibole and veinlets of carbonate. The later, potassic stage of alteration produced irregular aggregates and discontinuous veinlets of biotite. Finer grained (0.5–1 mm) mafic rocks, interpreted as altered hornblendites on the basis of relict texture, are associated with the diorite. These rocks have been altered to a mass of chlorite and carbonate with irregular aggregates of secondary biotite. A later stage of alteration deposited epidote in fractures and joints. At locality A, irregular, discontinuous, coarse-grained quartz–carbonate–epidote veins are associated with the diorite and are cut by later carbonate veinlets.

Magmatic–hydrothermal breccia dykes

Several swarms of magmatic–hydrothermal breccia dykes have been recognized in the northern occurrence of McHale Granodiorite. The dykes, which occur at all localities (A–G) in Figure 2, are 1–2 m wide and strike north to northeast. Although magmatic–hydrothermal breccia dykes intrude diorite at localities A, B and C, they are invariably associated with dykes and apophyses of leucocratic tonalite or granodiorite which cut the more mafic phase. The matrix-supported breccias contain abundant angular to rounded clasts, up to several centimetres across, in a strongly silicified matrix of rock flour (Fig. 3A–F). Clast types vary from locality to locality but are mainly quartz–feldspar porphyry (?felsic volcanic or subvolcanic rock), granitoid, vein quartz, and quartz and feldspar crystal fragments. Dioritic clasts are dominant where the dykes cut the relatively mafic phase of McHale Granodiorite. The clasts display variable alteration, mainly sericitization and silicification. Less commonly (e.g. GSWA 132841, locality A, Fig. 2), there are clasts of massive carbonate up to several centimetres across (Fig. 3C). Rounded clasts display evidence of hydrothermal ‘milling’ during violent, gas-charged eruption of the dyke material, and fluidization structures have been observed (Fig. 3E,F). Coarse, euhedral limonitic pseudomorphs and limonitic matrix (?after pyrite) have been observed in samples (GSWA 132839, 132840) from locality C (Fig. 2). In some samples, overprinting relationships indicate repeated stages of dyke formation and brecciation (Fig. 3B). Breccia dykes are cut by later quartz and carbonate veinlets.

Partial whole-rock analyses of some magmatic–hydrothermal breccia dykes from the area shown in Figure 2 are given in Table 1. The samples give little indication of anomalous metal contents except for sample 132840, which has a limonitic matrix and contains moderately high copper.

Discussion

Hydrothermal alteration in the McHale Granodiorite may be related to any or all of several processes.

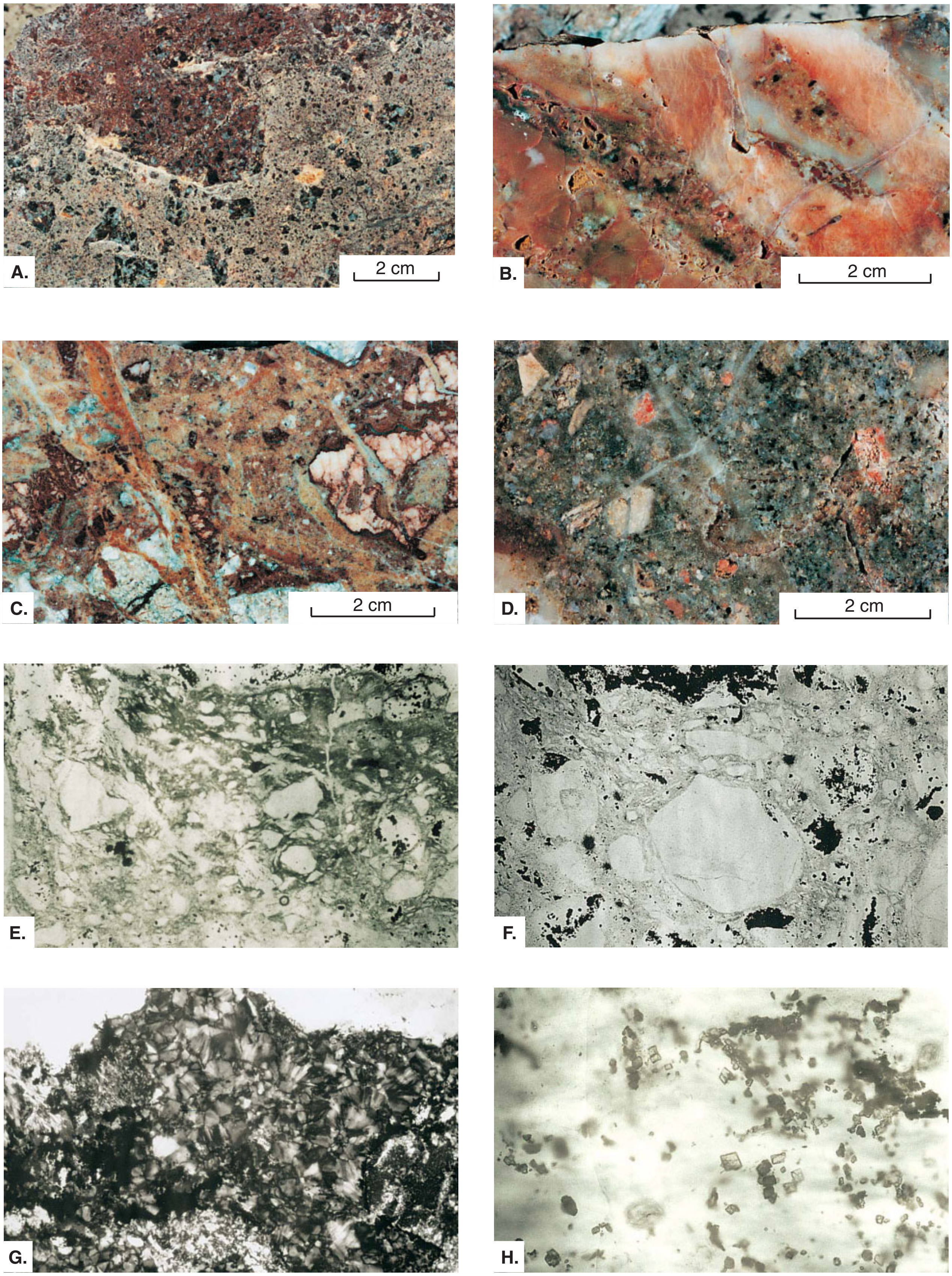
- Second boiling of McHale Granodiorite or other felsic magmas and subsequent circulation of magmatic (?and meteoric) fluids.
- Erosion and weathering at the unconformity at the base of the overlying Red Rocks Formation.
- Movement on the Halls Creek Fault.

However, the association of altered McHale Granodiorite with magmatic–hydrothermal breccia dykes strongly implies an important role for the first process.

Magmatic–hydrothermal breccias are produced by the violent release of hydrothermal fluids from magma chambers and are commonly located in the upper parts of plutons or stocks (Sillitoe, 1985). Rounded clasts are produced locally by attrition or milling (Sillitoe, 1985) or spalling as a result of decompressive shock (Kirwan, 1985). Fluidization structures record the gas-charged upwards streaming of particles in the high-energy environment that accompanies fluid saturation and second boiling of a magma at shallow crustal levels (Burnham, 1979).

The presence of magmatic–hydrothermal breccia dykes in the McHale Granodiorite is evidence of a shallow level of pluton emplacement and related hydrothermal activity, including second boiling. This feature is not easily reconciled with the coarse, equigranular texture of the McHale Granodiorite, which suggests a deeper level of pluton emplacement. This apparent inconsistency may indicate that hydrothermal fluid activity is related to an unexposed high-level pluton which post-dated emplacement of the McHale Granodiorite and subsequent uplift. There are two intrusive events which are known to post-date emplacement of the McHale Granodiorite. The Mount Christine Monzogranite (1810 Ma) and the San Sou Monzogranite (1790 Ma) have been identified mainly in the southern part of the Halls Creek Ororgen and are more felsic than the McHale Granodiorite.

A complex sequence of intrusion, dyke formation, brecciation, veining and hydrothermal alteration is evident in the northern occurrence of McHale Granodiorite. Based on



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initial observations, the sequence is as follows:

1. Intrusion of diorite and related rocks (e.g. hornblendites).

2. Intrusion of leucocratic tonalite and granodiorite with formation of pegmatite.

3. Emplacement of magmatic–hydrothermal breccias during second boiling of the McHale Granodiorite or an unexposed, subjacent pluton.

4. Hydrothermal alteration (propylitic alteration, potassic alteration, sericitization, silicification, argillic alteration) followed crystallization and release of hydrothermal fluids but may have partially overlapped brecciation as clasts commonly display a different style of alteration to the silicified rock-flour matrix.

5. Carbonation occurred during propylitic alteration and massive veins of carbonate contain fragments of breccia. However, massive carbonate clasts in some breccia dykes indicate overlap between carbonating fluids and brecciation. Carbonation continued during stage 5 as late, cross-cutting veinlets.

6. Epidote-rich veins and fracture-filling accompanied by varying amounts of carbonate.

Magmatic–hydrothermal breccia dykes, and the alteration styles documented in this paper (argillic alteration and residual silica enrichment), are commonly associated with porphyry and epithermal styles of mineralization — most commonly base and precious metals but also tin, tungsten and molybdenum (Sillitoe, 1985; Heald et al., 1987; Hedenquist et al., 1994). In some cases, the breccia dykes themselves are mineralized. The ocurrences described here may be related to a larger hydrothermal system, including mineralization at Mount Angelo South near Halls Creek which has been described as a possible porphyry copper deposit (Griffin et al., in prep.). This is consistent with estimates of sinistral movement along the Halls Creek Fault of at least 90 km (Tyler et al., 1995) and could indicate movement of up to 150 km.

Many of the small copper occurrences in and adjacent to the area described appear spatially related to the Halls Creek Fault

Table 1. Partial whole-rock geochemical analyses of magmatic–hydrothermal breccia dykes in the McHale Granodiorite, Halls Creek Orogen

Sample no.	*132836*	*132837*	*132838*	*132839*	*132840*	*132841*
Ti	521	769	3 371	429	880	420
Fe	2.35%	1.29%	2.34%	1.44%	13.7%	4.09%
Mn	253	181	20	77	2 096	1 751
Mg	861	1 094	188	468	1 430	9 630
Ca	2 594	2 785	240	418	387	10.1%
Na	207	1 532	92	282	290	4 428
K	9 000	1.18%	3 615	7 850	1.56%	8 750
P	168	276	374	113	836	223
As	5	3	-	5	-	-
Au	**-**	**3**	**-**	**50**	**-**	**-**
Ce	-	-	-	10	19	-
Co	-	2	-	-	19	-
Cr	174	435	139	557	188	135
Cu	26	59	14	50	1 838	65
Mo	-	-	-	-	9	-
Nb	-	-	8	-	-	-
Ni	5	7	-	8	20	9
Pb	20	16	30	14	16	8
Sb	4.2	1.4	0.8	7.4	1.2	1.0
Sr	3	13	136	59	77	111
Pd	**-**	**4**	**1**	**-**	**-**	**-**
U	2.6	2.7	3.7	2.5	4.5	1.9
V	17	21	73	14	26	34
W	0.5	0.7	2.9	0.7	1.0	0.3
Y	5	6	6	-	5	9
Zn	30	25	9	21	10	60
Zr	34	30	54	18	27	7

Notes: All analyses in ppm unless otherwise indicated (as % or in **bold type** which indicates **ppb**).

Ag (1 ppm), Bi (5 ppm), Cd (5 ppm), Sn(5 ppm), Pt (5 ppb) and Te (0.2 ppm) are all consistently below the lower limit of detection (shown in brackets) in all samples

132836, 132837 Magmatic–hydrothermal breccia dykes (locality G, Fig. 2); 132838 Magmatic–hydrothermal breccia dyke (locality F, Fig. 2); 132839 Magmatic–hydrothermal breccia dyke (locality D: Fig. 2); 132840 Magmatic–hydrothermal breccia dyke with limonitic matrix (locality D: Fig. 2); 132841 Magmatic–hydrothermal breccia dyke (locality A, Fig. 2).

Figure 3. Magmatic–hydrothermal breccia dykes from southeast of Turkey Creek, Halls Creek Orogen

A. GSWA 132838, locality F (Fig. 2), showing large, angular clasts of altered (silicified, argillized, hematitized) granitoid in a rock flour matrix
B. GSWA 132839, locality D (Fig. 2), showing late, very fine-grained breccia dykes (pink, chalcedonic appearance) cutting earlier, coarser breccia dyke
C. GSWA 132841, locality A, showing a breccia dyke with clasts of massive carbonate (upper right)
D. GSWA 132837, locality G (Fig. 2), showing detail of matrix; rounded ('milled') to angular clasts of hematitized granitoid (pink), felsic volcanic or subvolcanic rocks (white) and quartz and feldspar crystal fragments in a silicified rock-flour matrix
E. GSWA 132838, locality G (Fig. 2), photomicrograph of silicified breccia dyke matrix showing angular to rounded ('milled') rock and crystal fragments grading in size down to rock flour. The fine-grained disseminated dark material is hematite and diaspore. Plane polarized light; field of view is about 4 mm wide
F. GSWA 132838, locality F (Fig. 2), photomicrograph of rounded quartz crystal clast with indication of fluidized flow in matrix at top and top left of clast, and evidence of spalling of fragments of the top of the quartz-crystal clast. Plane polarized light; field of view is about 4 mm wide
G. GSWA 132835, locality F, Fig. 2), photomicrograph of probable interlayered kaolinite/illite after feldspar in altered McHale Granodiorite. Crossed polars; field of view is about 1.5 mm wide
H. GSWA 132835, locality F (Fig. 2), photomicrograph of disseminated anatase from altered feldspar domain in McHale Granodiorite. Plane polarized light; field of view is about 0.5 mm wide

system. These could have been deposited, along with hematite, epidote and carbonate, from oxidized fluids during movement on the faults. However, magmatic–hydrothermal breccia dykes, propylitic and potassic alteration, silicification and argillization record the presence of magmatic to early post-magmatic hydrothermal activity, which may have been accompanied by as yet undiscovered base and precious metal mineralization.

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