The revised GSWA rock classification scheme

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Abstract

A four-tier, hierarchical rock classification scheme provides a consistent approach to lithological nomenclature within the Geological Survey of Western Australia (GSWA). Sedimentary, igneous, and metamorphic rocks are classified using objective criteria observable in all rocks, at outcrop, hand-specimen, or thin-section scale. The scheme conforms mostly to internationally recognized classification schemes, apart from the approach to classification of some volcanic rocks.

Introduction

Revision of GSWA's rock classification scheme is a response to the increasing number of digital products extracted from corporate databases, and the requirement that such products employ consistent terminology. The revision provides the opportunity to clarify the usage of certain terminology within GSWA. As GSWA is a field-based organization, the scheme relies on features observable in all rocks at outcrop scale, in hand specimen, and in thin section. This paper provides an overview of the scheme, together with examples of how it is applied. Further details are available on request.

A successful rock classification scheme has to be applicable within all tectonic units and geological settings, and throughout the geological column, which in Western Australia extends back to the Eoarchaean (3.73 Ga). Such a classification scheme also acts as a guide for creating map unit codes for display on map products, and forms the basis for the entry into, and the searching of, all information on lithologies and rock types within GSWA databases. Throughout the revision process, every attempt has been made to develop a set of map unit codes that closely follows those used on GSWA map products in the past to ensure a degree of continuity. The new scheme has been tested on GSWA's East Yilgarn Geoscience Database (Riganti and Groenewald, 2004).

A revised approach to the classification of regolith in GSWA (Hocking et al., 2001) aimed to be 'uniform, comprehensive, flexible, and reasonably intuitive'. It employed a hierarchical approach, from the highest-level landform setting and process, down to regolith composition, and then parent rock type or cement. The scheme allowed the creation of detailed map unit codes that could be 'rolled up' to a higher level for use at progressively smaller map scales. The same aims and principles have been applied to the revised rock classification scheme; the highest-level divisions (sedimentary, igneous, and metamorphic) are further divided following the principles of established or proposed international schemes where available, or follow well-established principles where such schemes are unavailable.

Sedimentary, igneous, and metamorphic rocks are classified using different criteria, although all use a four-fold hierarchical approach. As an example, a coarse-grained rock with a porphyritic 'igneous' texture consisting of quartz (>20%), equal proportions of plagioclase and K-feldspar, and biotite is defined as a monzogranite. From the rock name, a higher level, more genetic classification is implied: that it is igneous, intrusive, and has a broad granitic composition. When translated into a map unit code, the starting point is its granitic composition and texture (granitic – g), followed by subdivision based on its mineral content and mode (monzogranite – m), and then by its specific mineralogy (biotite – b) and particular texture (porphyritic – p). The resulting code is 'gmbp'. These levels can also be used as searchable fields in attribute tables for use with Geographic Information System (GIS) software. Further examples of this approach are given in Table 1.

Sedimentary rocks

Sedimentary rocks are initially classified as 'siliciclastic', 'carbonate', or 'other chemical or biochemical'. Siliciclastic rocks (s) are subdivided by a secondary code according to grain size (e.g. sandstone – st), and further qualified by a tertiary qualifier according to composition (e.g. quartzose – stq). Subdivision of carbonate rocks (k) is initially based on composition (e.g. limestone – kl), then on grain size or texture, based in part on the schemes of Dunham (1962) and Tucker (1991), which are suited to field mapping (e.g. calcarenite – kla). Other chemical and biochemical rocks (c) are treated in a similar way to carbonate rocks, and are classified according to composition (e.g. iron formation – ci), which can then be further qualified according to grain size, texture (e.g. granular – cig), or further compositional criteria (e.g. jaspilitic – cij). All three divisions of sedimentary rocks make use of the same set of environmental quaternary qualifiers (e.g. alluvial – stqa).

In the scheme, the terms 'arenite' and 'wacke' are only used where petrography has established the amount of matrix present; otherwise the rock is classified as sandstone. Arenite refers to sandstone with less than 10% matrix, and wacke to sandstone with more than 10% matrix (Dott, 1964). The preferred terms for a fine-grained sedimentary rock are mudstone or siltstone. Shale is restricted to a fine-grained sedimentary rock with a shaly parting. Rudite and argillite are not used, as they are synonymous with conglomerate, and mudstone or siltstone, respectively. Quartz sandstone is preferred to quartzite or orthoquartzite, as quartzite is defined here as a metamorphic rock, not as an intensely silicified sandstone.

In some cases, there is textural and compositional overlap between sedimentary rocks that contain volcanic clasts and those that are true volcaniclastic deposits. A sedimentary rock is not classified as volcaniclastic simply because it contains some volcanic material. The sedimentary rock classification scheme should be used for clastic rocks in which: the overall stratigraphic context of the rock unit is dominantly non-volcanic; the rock comprises a mixture of non-volcanic clasts and subordinate volcanic clasts; the volcanic clasts are of different composition and type; or the volcanic clasts are rounded and well sorted.

Igneous rocks

Volcanic rocks

A volcanic rock is defined as an igneous rock that has formed on or near the Earth's surface (Jackson, 1997, p. 704). Therefore, the revised GSWA classification scheme uses volcanic terminology for hypabyssal or sub-volcanic rocks (such as dykes, sills, and cryptodomes) that are both spatially and temporally associated with extrusive volcanic rocks. Intrusive rock nomenclature can be used for rocks that may be coarse-grained parts of an extrusive succession, such as dolerite or gabbro, found amongst demonstrable flow successions.

The GSWA classification scheme has adopted a descriptive rather than a genetic approach to the classification of volcanic rocks, which is appropriate for the poorly exposed, altered, weathered and/or metamorphosed successions (Cas and Wright, 1987; McPhie et al., 1993) common in Western Australia. This is in contrast to the more genetic approach adopted by the International Union of Geological Sciences (IUGS; Le Maitre, 2002).

The Geological Survey of Western Australia adopts a more restricted definition for pyroclastic rocks than the IUGS. The IUGS definition of 'pyroclastic deposits' includes all material with more than 75% by volume of pyroclasts, irrespective of the history of transportation, deposition, and resedimentation. In the GSWA scheme, the use of 'pyroclastic' is reserved for primary volcaniclastic deposits, composed of fragments (pyroclasts) generated by explosive eruptions, which have undergone single-phase transport and have been deposited directly by volcanic processes (i.e. pyroclastic fall, surge, or flow; Fisher, 1966).

Consistent with emphasizing the importance of field observations in classification, the revised GSWA classification scheme uses the term 'komatiite' for ultramafic rocks with olivine spinifex texture, or rocks spatially associated with such rocks (e.g. mesocumulates or orthocumulates). Rocks with MgO contents between those of tholeiitic basalts and komatiites (roughly 6–18% MgO) — termed 'high-Mg basalts' in many GSWA publications — are common in Western Australia. In the revised GSWA scheme, the term high-Mg basalt has been abandoned because: not all rocks thus classified have a high MgO content; textural criteria taken as indicative of high MgO contents (e.g. varioles or ocelli) are not confined to rocks with high MgO contents; and some high MgO rocks do not have ocelli or varioles. However, in most cases, rocks with randomly oriented acicular pyroxene (usually replaced by amphibole) have elevated MgO contents of about 10 to 18%. Because these rocks are usually spatially associated with komatiites, and the texture is similar to olivine spinifex texture found in komatiites, such rocks are termed pyroxene spinifex-textured basalts. The term 'komatiitic basalt' is used for rocks which, when analysed, have elevated MgO contents (usually 10–18%) but no textural information to indicate such elevated MgO levels. Units with varioles or ocelli are named accordingly (e.g. 'ocellar basalt' or 'variolitic basalt').

Examples of the revised GSWA classification scheme (Table 1) illustrate the use of the four-letter hierarchical coding system for volcanic rocks. The mandatory primary code provides a broad compositional subdivision (felsic volcanic – f; mafic volcanic – b; ultramafic volcanic – u; feldspathoid-bearing volcanic – l; undivided – n). The secondary code is a more detailed compositional breakdown into lithology (e.g. basalt – bb), whereas the tertiary code contains textural features for coherent units (e.g. pillowed – bbo) and a grain-size breakdown for volcaniclastic units (e.g. volcanic breccia – bbx). The quaternary code includes options for indicating alteration (e.g. carbonate-altered – bbxk), or textural features more strongly aligned with a genetic classification (e.g. lithic-rich – bbxt). In one example (pillowed basalt with radiating pipe vesicles), the scheme does not accommodate the coding of both 'pillowed' and 'vesicular'. In this

Table 1. Examples of the revised GSWA rock classification scheme

Description	*Primary*	*Secondary*	*Tertiary*	*Quaternary*	*Comment*	*Code*
Ferruginous chert	c – other chemical or biochemical	c – chert	i – ferruginous			cci
Polymictic conglomerate interbedded with sandstone; of glacial origin	s – siliciclastic	g – conglomerate and sandstone (conglomerate>sandstone)	p – polymictic	g – glacial		sgpg
Stromatolitic carbonate, with subordinate siliclastic component; back reef	k – carbonate	t – carbonate with minor siliciclastic component	s – stromatolitic	b – back reef		ktsb
Pillow basalt with radiating pipe vesicles	b – mafic volcanic	b – basalt	o –pillowed g – vesicular/amygdaloidal	–	Scheme does not allow for coding of both pillowed and vesicular (both are tertiary codes). Code for one that is most prominent or significant, and put the omitted term in the legend	bbo or bbg
Fragmental komatiite (possible near-vent deposit)	u – ultramafic volcanic	k – komatiite	x – volcanic breccia	–	Could further qualify using a quaternary code for monomictic (u) or vitriclastic (v)	ukx
Komatiitic peperite	u – ultramafic volcanic	k – komatiite	x – breccia	x – sediment-matrix rich		ukxx
Rhyolitic ignimbrite	f – felsic volcanic	r – rhyolite	s – volcanic breccia-sandstone	g – pumice-lithic		frsg
Dacite accretionary lapilli-bearing tuff	f – felsic volcanic	d – dacite	t – volcanic sandstone (grain size equivalent to tuff)	h – accretionary lapilli-bearing		fdth
Monzogranite with muscovite and tourmaline	g – granitic	m – monzogranite	v – muscovite	t – tourmaline		gmvt
Banded olivine norite	o – mafic intrusive	r – olivine norite	y – layered/banded	–	Part of a layered mafic intrusion	ory
Brecciated, goethite-bearing vein quartz	z – hydrothermal	q – vein quartz	i – goethite/hematite	x – brecciated		zqix
Amphibolite after basaltic volcanic and volcaniclastic rocks	m – metamorphic b – mafic	v – metavolcanic and metavolcaniclastic b – basaltic	w – mafic a – aphanitic	a – amphibole/ hornblende	Metamorphic code emphasizes metamorphic features; igneous code emphasizes protolith	mvwa or bba
Schistose, sillimanite-bearing, interlayered pelite and psammite	m – metamorphic	h – psammite and pelite, interlayered	s – schistose	l – sillimanite	Structural code (s) precedes mineralogical code (l)	mhsl
Orthopyroxene-bearing quartzofeldspathic gneiss (protolith unknown)	m – metamorphic	n – gneiss	f – felsic/feldspathic/ K-metasomatized	o – orthopyroxene	–	mnfo

Table 1. (continued)

Description	*Primary*	*Secondary*	*Tertiary*	*Quaternary*	*Comment*	*Code*
Schistose, muscovite-bearing metagranite	m – metamorphic	g – metagranitic	s – schistose	m – muscovite	–	mgsm
Metabasalt interleaved with foliated granitic rock	x – mixed rock types	mbb – metamorphosed basalt	mg – metagranitic	–	–	xmbb-mg
Interleaved mafic and ultramafic schist	x – mixed rock types	mus – ultramafic schist volcanic	mbs – schistose metamafic	–	–	xmus-mbs
Granitic rock with mafic volcanic xenoliths	j – xenolith bearing	g – granitic (predominant) (subordinate; xenolith phase)	b – mafic volcanic	–	–	jg-b

case, the dominant or most significant feature should be included in the code, and any other features described in the legend.

Intrusive and other igneous rocks

The GSWA approach to the classification of plutonic rocks (i.e. coarse-grained, intrusive rocks, indicating crystallization at considerable depth) largely follows that of the IUGS (Le Maitre, 2002), which is based on modal mineralogy, rather than chemistry. The IUGS recommend a grain size of greater than 3 mm for a rock to be classified as coarse grained, and this scheme is adopted here with the exception of the 'igneous other' category, which is reserved for lithologies where the rock name is not dependent on the rock's grain size or mode of occurrence.

All intrusive igneous rocks with a grain size of less than 3 mm contain the prefix 'micro', in accord with IUGS recommendations. For two discrete mappable rock units that differ only in grain size (e.g. fine grained versus medium grained), grain size is incorporated into the codes with a textural and mineralogical qualifier.

Recent practice in GSWA has been to give layered mafic–ultramafic intrusions a primary compositional code of 'a', in order to distinguish them from massive mafic and ultramafic intrusions ('o' and 'u', respectively). This practice is contrary to the IUGS scheme, which classifies rocks according to their mineral content or mode, and not according to the form of the intrusion that hosts the rocks. Therefore, rocks within layered mafic–ultramafic intrusions are now coded according to their composition only (mafic or ultramafic).

There are a number of terms in widespread usage that convey useful information, or are very entrenched in the literature, yet do not conform to the IUGS scheme. For example, the terms 'dolerite', 'pegmatite', and 'granophyre' are in wide use, and have therefore been retained in the new GSWA scheme. However, the terms 'aplite' and 'porphyry' have been abandoned, as they do not convey any useful information about the rock, and suitable compositions (e.g. microsyenogranite) can be used instead.

In the classification of intrusive rocks, the primary code identifies the general compositional type of intrusive igneous rock (granitic – g, mafic intrusive – o, ultramafic intrusive – a, foid-bearing intrusive – d), whereas the secondary codes allow classification of common lithologies (e.g. 'm' for monzogranite). The tertiary codes mainly deal with grain size (e.g. very coarse grained – gmd), although other tertiary and quaternary codes deal with both texture (e.g. equigranular – gme) and mineralogy (e.g. hornblende – gmeh). For 'other igneous rocks', the primary code identifies the general compositional type of igneous rock (lamproite – i, lamprophyre – y, kimberlite – p, carbonatite – r, melilitic rock – e, and kalsilitic rock – w), and the secondary codes offer a means of subdividing these broad groupings into common lithologies (e.g. the lamprophyre vogesite is coded – lv). Grain-size terms (e.g. fine, medium, very coarse) are restricted to the tertiary codes only, and other textural and mineralogical criteria can be specified by tertiary or quaternary codes.

Hydrothermal rocks

Hydrothermal rocks (z) include veins, and massive and bedded material. Gossan is regarded as a regolith unit, not a product of hydrothermal activity.

Metamorphic rocks

The GSWA scheme for metamorphic rocks is based on the recommendations of the IUGS Subcommission on the Systematics of Metamorphic Rocks (SCMR; Schmid et al., 2002), with structural terms following Brodie et al. (2002). Any scheme for classifying and coding metamorphic rocks will be complex, as it must be consistent with the classification of the igneous or sedimentary protolith of the metamorphic rock, and must also cater for classification according to the processes associated with metamorphism.

Under the revised GSWA scheme, metamorphic rocks can be classified in two ways:

- A rock can be named by prefixing the appropriate protolith rock name with 'meta' (e.g. metabasalt, metasandstone) where the protolith is known. A protolith rock name that requires the recognition of a specific primary texture, primary mineralogy, or chemical composition should not be used with a 'meta' prefix if the primary feature has been destroyed or altered by metamorphic processes. Where primary structures are no longer obvious, an approved specific metamorphic rock name can be applied to the unit (usually implying the protolith). This name is based on metamorphic mineralogy, and reflects composition and metamorphic grade or process (e.g. amphibolite, marble, and skarn). The scheme also provides codes for metamorphic rocks where some general inference can be made on the origin of the rock (e.g. mafic igneous rock, whether intrusive or volcanic).
- Where the protolith is unknown, metamorphic rocks can be either classified by applying the IUGS SCMR recommended structural root terms (schist, gneiss, and granofels), or classified as the product of a specific metamorphic process (impactite, fault rock, and metasomatic rock).

In both cases the meta(protolith) name, the specific name, or the structural root or process terms can be combined with composition or mineral qualifiers to complete the metamorphic rock name.

Where characteristic compositions, lithological features, original layering, and stratigraphic relationships are readily distinguishable, lower grade metamorphic rocks (usually up to and including greenschist facies) can be treated as unmetamorphosed sedimentary and igneous rocks. Where the degree of deformation and recrystallization varies within a sequence of lower grade rocks (e.g. in Archaean greenstone belts), units coded according to preserved sedimentary and igneous features (e.g. pillowed basalt – bbo) can exist alongside those coded for metamorphic features (e.g. mafic schist derived from a basalt – mbbs).

The primary code (m – metamorphic) is mandatory. A combined secondary and tertiary code is applied to protolith rock names with 'meta' prefixes and to specific rock names, and generally follows the igneous or sedimentary protolith code (e.g. metabasalt – mbb, metamonzogranite – mgm, and metasandstone – mt). Where the protolith in unknown, the structural root or metamorphic process terms are used (schist – s, gneiss – n, granofels – e, impactite – p, fault rock – y, and metasomatic rock – z). Tertiary and quaternary qualifiers include structural and textural terminology, composition, mineralogy, and alteration. The same tertiary or quaternary code letter can be used for more than one qualifier, as the context, denoted by the secondary or tertiary code letter, can be different (e.g. metagranodiorite – mgg; garnet-bearing pelite – mlg).

The scheme allows for coding of compositionally similar rocks in a number of ways, depending on what feature is to be emphasized. For example, a metamorphic rock derived from a monzogranite could be classified as a felsic meta-igneous rock (mr), a metagranite (mg), a schistose granitic rock (mgs), a felsic schist (mrs), a mylonitic granite (mgy), or a cataclastic fault rock (myxf).

Mixed lithologies, and inclusion- or xenolith-bearing lithologies

Many mappable units contain more than one lithology or rock type. When applying a rock classification scheme in the construction of lithological map unit codes for a mappable unit at any scale, emphasis should be placed initially on the predominant lithology or rock type, or a diagnostic or significant lithology or rock type within the unit (i.e. the feature that makes the unit distinguishable from adjacent mappable units). The principles are those discussed for lithostratigraphic units in the International Stratigraphic Guide (Salvado, 1994, p. 31–43). Mixtures of lithologies within rock types where no one lithology is predominant are best dealt with within each classification scheme by creating an appropriate code if necessary. For example, within the 'sedimentary siliciclastic' classification, siltstone/mudstone would appear as 'sl', and interbedded sandstone and siltstone as 'ss'.

There are mappable units that at the highest level of division represent mixtures of sedimentary, igneous, and metamorphic rocks, and units at a lower level of division that are mixtures of rock type. In these cases an 'x' is used in place of a primary rock type code and is followed by two bedrock codes, in order of predominance, separated by a hyphen (e.g. *lit-par-lit* intrusion of granitic rocks into igneous mafic volcanic rocks at a greenstone belt margin – xg-b; interbedded carbonate and ultramafic rocks – xk-u).

In some cases it is necessary to code a mappable unit that has abundant inclusions or xenoliths, such as in granite–greenstone terranes where the margins of granite bodies have abundant greenstone xenoliths. In this case, the code 'j' is used in a similar way as 'x' for mixed rock types as a primary code. Thus, 'jg-b' is granitic rock with mafic volcanic xenoliths, whereas 'jo-g' is gabbro with granitic xenoliths.

Conclusions

The revised GSWA rock classification scheme aims to be flexible and intuitive. Consistent with GSWA being a field-based organization, classification is based on the objective observation of features at the outcrop, hand-specimen, and thin-section scale. Attempts have been made to follow accepted international recommendations for lithological classification and nomenclature, and this has been largely achieved. Most notable exceptions are in the classification of volcanic rocks: the GSWA and IUGS schemes diverge when it comes to identifying pyroclastic rocks, the IUGS scheme uses chemistry in classification, and there are differences between the GSWA and IUGS approaches to nomenclature and classification of volcanic rocks with elevated MgO contents.

Revision of the nomenclature of rocks in GSWA has also provided the opportunity to clarify the organization's usage of common terms that do not strictly conform to the classification and nomenclature guidelines. Some terms have been retained, whereas others have been abandoned.

Although sedimentary, igneous, and metamorphic rocks form by different geological processes, the revised classification scheme attempts to provide a common approach to classification of all rock types by adopting a four-tier hierarchical coding scheme. Although map unit codes are largely based on objective criteria, quaternary codes allow more-genetic criteria to be included in the classification.

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