Nomenclature of Precambrian Rocks in Colorado

GEOLOGICAL SURVEY BULLETIN 1422-D

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By OGDEN TWETO

CONTRIBUTIONS TO STRATIGRAPHY

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An appraisal of existing nomenclature and measures needed for improvement

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NOMENCLATURE OF PRECAMBRIAN ROCKS IN COLORADO

By OGDEN TWETO

ABSTRACT

The Precambrian rocks of Colorado consist of a metamorphic complex more than 1,700 million years in age, three groups of igneous rocks about 1,700, 1,400, and 1,000 nillion years in age, here designated informal age groups, and two areally restricted units of sedimentary rocks, one between 1,400 and 1,700 million years in age and one between 950 and 1,400 million years. A systematic nomenclature for many of the rocks does not exist, but the present state of knowledge will permit establishment of a comprehensive nomenclature. Numerous formal names that have been applied to elements of the Precambrian assemblage are appraised and classified in a table, and eight names are abandoned.

INTRODUCTION

As presently understood, the Precambrian rocks widely exposed in the mountains of Colorado (fig. 1) are a composite of six major age or genetic classes:

1. A metamorphic complex >1,700 m.y. (million years) in age.
2. A group of igneous rocks about 1,700 m.y. in age.
3. A unit (Uncompahgre Formation) of moderately metamorphosed sedimentary rocks <1,700 m.y. and >1,400 m.y. in age.
4. A group of igneous rocks about 1,400 m.y. in age.
5. A group of igneous rocks about 1,000 m.y. in age.
6. A unit (Uinta Mountain Group) of slightly metamorphosed sedimentary rocks provisionally dated as 950 to 1,400 m.y. in age.

No system of formal stratigraphic nomenclature exists for many of these rocks. Many stratigraphic names have been proposed, but most of them apply only to bits and pieces of the total assemblage. Before the advent of radiometric dating and widespread detailed mapping, many units were defined without knowledge of temporal relationships

and with little consideration of their relation to rocks in other parts of the State or geologic province. Among those correlations that were made, many have subsequently proved faulty, and most of the few formal groups or "series" that were erected have proved to be based on faulty interpretations or assumptions. Thus, by a process of elimination, the nomenclature of Precambrian rocks in Colorado has been reduced to a rudimentary state. Fortunately, though no action has yet been taken, knowledge is now at hand to improve it.

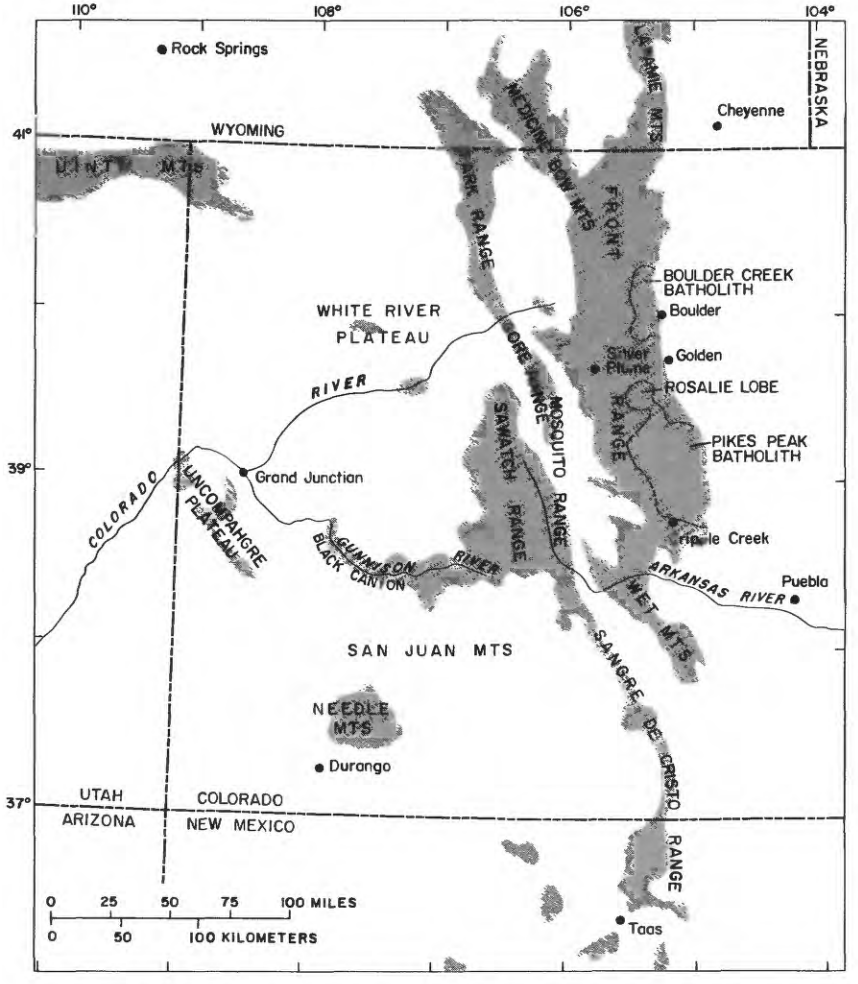

FIGURE 1.—Parts of Colorado and adjoining States showing distribution of Precambrian rocks (shaded areas) and localities mentioned in text and in table 1.

A total of 93 formal names applied to Precambrian rocks is recorded in the U.S. Geological Survey's computer printout of stratigraphic names

in Colorado. Though it is not the purpose here to denigrate the work of the past, the fact is that many of these names were inadequately defined or improperly introduced, and many that are technically valid are applicable only in minuscule type areas. A few names have been widely misapplied and have thereby lost whatever stratigraphic value they may have had originally. Still others have become obsolete through disuse or reclassification. Of all the names that have been proposed, only about 30 percent remain valid and in current use, and most of these are for igneous rocks.

As an outgrowth of the preparation of a new geologic map of Colorado, (Tweto, 1976), the formally named Precambrian stratigraphic units have been appraised and classified (table 1). For reasons indicated in the table and discussed under following headings, several names applied in the past by the U.S. Geological Survey are herein abandoned. Many other names, established by other parties, are obsolete or fail to meet the requirements of Article 13 of the Stratigraphic Code (American Commission on Stratigraphic Nomenclature, 1970). Use of such names without amendment or redefinition is inadvisable.

Though no attempt is made in this report to define new stratigraphic units appropriate to the Precambrian rocks, courses of action are considered in the section headed "Discussion."

PRE-1,700-M.Y. METAMORPHIC COMPLEX

A suite of complexly deformed metamorphic rocks of generally high rank forms a matrix for the abundant Precambrian igneous bodies in Colorado and a basement for the two younger Precambrian sedimentary sequences. This suite, herein referred to as the pre-1,700-m.y. metamorphic complex, consists of many varieties of metamorphic rocks, reflecting the permutations of varied parent materials, considerable range in degree of prograde metamorphism, wide range in degree of penetrative deformation, and wide range in degree of modification resulting either from igneous processes or retrograde metamorphism. The parent materials were evidently sedimentary, volcanic, and subvolcanic intrusive rocks. These ancestral rocks were in large discrete bodies in some places and closely interlayered or intertongued in others. They were a part of a huge province of rocks of similar age that are now irregularly exposed from southeastern Wyoming through Colorado into New Mexico and Arizona.

A minimum age for the rocks in the metamorphic complex is established by the fact that they were invaded by granites that are about 1,700 m.y. old. Geologic relations establish that metamorphism and folding both preceded and accompanied granitic intrusion. Radiometric age determinations indicate that regional metamorphism peaked in the period 1,700–1,775 m.y. ago in Colorado (Hedge and others, 1967; Hedge

TABLE 1.—*Classification of Precambrian rock units in Colorado*

[Names in current use by U.S. Geological Survey indicated by **. Names adopted in past for use by U.S. Geological Survey but currently in limited use indicated by * Precambrian time divisions: Y, 800–1,600 m.y.: X, 1,600–2,500 m.y. W, >2,500 m.y. Fm., Formation; Mbr., Member; cent., central]

Unit	General area	Original reference	Discussion	Reference for age data or for current treatment in mapping
Rocks of pre-1,700-m.y. metamorphic complex (Precambrian W)				
Red Creek Quartzite** or Complex.	Uinta Mountains	Powell (1876)	Inferred to be part of Precambrian W age province of Wyoming; radiometric age of 2,320 m.y. is a minimum and is interpreted to mark a younger metamorphic event.	Hansen (1965).
Rocks of pre-1,700 m.y. metamorphic complex (Precambrian X)				
Belcher Hill Fm.	E.-cent. Front Range	Lickus and LeRoy (1968)	One of several units defined in narrow belt along mountain front near Golden; of doubtful application elsewhere; assumed direction of stratigraphic sequence is debatable.	Sheridan, Maxwell, and Albee (1967).
Big Thompson Schist	NE Front Range	Fuller (1924)	Obsolete; name not used in type area in recent decades	Braddock and others (1970).
Black Canyon Schist*	Gunnison River	Hunter (1925)	In very limited use; impractically distinguished from River Portal Mica Schist.	Hansen (1971); Olson and Hedlund (1973).
Cedar Gulch Fm.	E.-cent. Front Range	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Sheridan, Maxwell, and Albee (1967).
Chase Ranch Quartzite Mbr. (Cressmans Gulch Fm.).	...do	...do	...do	Van Horn (1972).
Clear Creek Canyon Fm.	...do	...do	...do	Van Horn (1972); Scott (1972).
Clear Creek Gneiss	...do	Underhill (1906)	Obsolete; not used since introduction; name Idaho Springs Fm. applied to same rocks in same year.	Sheridan and Marsh (1976); Taylor (1976).
Coal Creek Quartzite	...do	Boos and Boos (1934)	Invalid; incidental mention without definition; rocks generally mapped as lithic unit or "quartzite of Coal Creek."	Wells (1967); Wells, Sheridan, and Albee (1964).
Crawford Gulch Fm.	...do	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Sheridan, Maxwell, and Albee (1967).
Cressmans Gulch Fm.	...do	...do	...do	Van Horn (1972).
Dubois Greenstone**	Gunnison River	Hunter (1925)	Unit of varied metavolcanic and subordinate metasedimentary rocks characterized by relict primary structures.	Olson and Hedlund (1973); Hedlund and Olson (1975).
Falcon Granite Gneiss	E.-cent. Front Range	Boos (1946)	Invalidly introduced; later abandoned by Boos, who in 1954 applied name Mount Morrison Fm. to same rocks.	Scott (1972); Bryant, Miller, and Scott (1973).
Golden Gate Canyon Fm.	...do	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Van Horn (1972).
Gooseberry Gulch Series	S. Front Range	Heinrich, Salotti, and Reuss (1968).	Invalid; does not conform with Stratigraphic Code; formal name not used in later report (Reuss, 1974).	Reuss (1974).
Green Ranch Quartzite Mbr. (Junction Fm.).	E.-cent. Front Range	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Sheridan, Maxwell, and Albee (1967).
Gunnison River Series	Colorado	Burbank and others (1935)	Abandoned herein; unit included most, but not all, of metamorphic rocks in State; name not used since introduction.	See most other references to metamorphic rocks in this column.
Holy Cross Schist	Sawatch Range	Stark and Barnes (1935)	Obsolete; name not used since introduction; unit impractically distinguished from Sawatch Schist.	Tweto (1974).

Idaho Springs Fm.*	Cent. Front Range	Ball (1906)	Name originally applied to predominantly biotitic and pelitic schists and gneisses in central Front Range; indiscriminate extension has made it a wastebasket for a compositional suite of metamorphic rocks; in such usage, term has no stratigraphic meaning; name is ignored in favor of lithic units on most modern maps, including type area.	Moench (1964); Sims and Gable (1964); Hawley and Moore (1967); Braddock (1969); Taylor (1976); Hedge, Peterman, and Braddock (1967).
Idledale Fm.	E.-cent. Front Range	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Scott (1972); Bryant, Miller, and Scott (1973).
Irving Fm.**	Needle Mountains	Cross and others (1905)	Originally, Irving Greenstone; redefined and application extended by Barker (1969).	Barker (1969).
Junction Fm.	E.-cent. Front Range	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Van Horn (1972).
Mitchell Gulch Fm.	Arkansas River	Salotti (1962)	Defined as being less metamorphosed, and therefore younger, than Idaho Springs Fm., and older than Pikes Peak Granite; however, the granite that cuts unit is not Pikes Peak but of Boulder Creek type and age.	Taylor, Scott, and Wobus (1975); Taylor and others (1975).
Mount Morrison Fm.	E.-cent. Front Range	Boos (1954); Boos and Boos (1957).	Name applied to the "quartz monzonite gneiss" of Ball (1906) and Lovering and Goddard (1950); informal terms felsic gneiss or quartzofeldspathic gneiss used on recent maps.	Bryant, Miller, and Scott (1973); Scott (1972); Hedge, Peterman, and Braddock (1967).
Mount Vernon Canyon Fm.	...do.	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Scott (1972); Sheridan, Reed, and Bryant (1972).
Needle Mountains Group	Needle Mountains	Cross and others (1905)	Abandoned herein; included metasedimentary rocks of two vastly different sequences: the Uncompahgre Fm. and the Vallecito Conglomerate, which are separated stratigraphically by the Irving Fm., Twilight Gneiss, and granites of ~1,700-m.y. age group.	Barker (1969).
Phantom Canyon Quartzite	S. Front Range	Martinez (1959)	Invalid; incidental mention in an abstract.	Scott and others (1976).
Ralston Fm.	E.-cent. Front Range	Boos and Boos (1934)	Invalid; incidental mention without definition; name preoccupied	Sheridan, Maxwell, and Albee (1967).
Ralston Buttes Fm.	...do.	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Do.
River Portal Mica Schist	Gunnison River	Hunter (1925)	Abandoned herein; impractically distinguished from Black Canyon Schist; not recognized in recent mapping.	Hansen (1971); Hansen and Peterman (1968).
Salida Schists	Arkansas River	Cross (1893)	Abandoned herein; not used since inadvertent introduction (context indicates formal name not intended).	Taylor, Scott, and Wobus (1975); Van Alstine (1974).
Sawatch Schist	Sawatch Range	Stark and Barnes (1935)	Invalid; name preoccupied; obsolete, name not used since introduction.	Brock and Barker (1972); Tweto (1974).
Swandyke Hornblende Gneiss.	Cent. Front Range	Lovering (1935)	Abandoned herein; name applied to a lithic type that occurs in many stratigraphic positions in metamorphic complex; indiscriminate application has given term a purely compositional connotation and destroyed whatever stratigraphic status it originally had.	Barker and Wyant (1976); Hedge, Peterman, and Braddock (1967).
Turkey Creek Canyon Fm.	E.-cent. Front Range	Lickus and LeRoy (1968)	See Belcher Hill Fm.	Bryant, Miller, and Scott (1973).
Twilight Gneiss**	Needle Mountains	Cross and others (1905)	Originally, Twilight Granite; redefined and volcanic and intrusive-sill origin established by Barker (1969).	Barker (1969); Silver and Barker (1968).
Vallecito Conglomerate**	...do.	...do.	Originally was assigned with Uncompahgre Fm. to Needle Mountains Group; later was established by Barker (1969) to be older than the Irving Fm. and Twilight Gneiss, upon which the Uncompahgre rests unconformably.	Do.
Westwater Gneisses and Schists.	Uncompahgre Plateau	Keyes (1924)	Invalid; incidental mention of name only	Case (1966); Hedge and others (1968).
Womack Gneiss	S. Front Range	Lindgren and Ransome (1906).	Abandoned herein; name was applied to small body of gneiss surrounded by Cripple Creek Granite at Cripple Creek.	Scott and others (1976).

TABLE 1.—*Classification of Precambrian rock units in Colorado*—Continued

Unit	General area	Original reference	Discussion	Reference for age data or for current treatment in mapping
Sedimentary rocks of post-1,700 m.y. age (Precambrian Y and X)				
Uinta Mountain Group**	Uinta Mountains	Burbank and others (1935)	Name and rank were changed from original and invalid "Uinta sandstone"; group has not been subdivided in Colorado; in Utah, provisionally dated at 950 to 1,400 m.y. (Precambrian Y) (Crittenden and Peterman, 1975).	Hansen (1965); Crittenden and Peterman (1975).
Uncompahgre Fm.**	Needle Mountains	Cross, Howe, and Ransome (1905).	Removed from Needle Mountains Group (abandoned); unit is younger than granites of ~1,700-m.y. age group and older than granites of ~1,400-m.y. age group (Barker, 1969); Precambrian Y and X.	Barker (1969).
Granitic rocks of ~1,700-m.y. age group (Precambrian X)				
Bakers Bridge Granite**	Needle Mountains	Barker (1969)	Exposed only in one stock	Barker (1969); Bickford and others (1969).
Boulder Creek Granite** or Granodiorite** or Granite Gneiss.	Cent. Front Range	Boos and Boos (1934) (as Granite Gneiss); Lovering and Goddard (1939) (as Granite).	Type body is batholith west of Boulder; rock of this body is leading example of granitic rocks of ~1,700-m.y. age group; informal term "Boulder Creek complex" has been applied to cluster of plutons similar to Boulder Creek in cent. Front Range (Hickling and others, 1970).	Peterman, Hedge, and Braddock (1968); Stern, Phair, and Newell (1971); Phair, Stern and Gottfried (1971).
Broncho Mountain Granite	Sawatch Range	Crawford and Worcester (1916).	Obsolete; not used since introduction; applied to an isolated small body.	Tweto and others (1976).
Browns Pass Quartz Monzonite**.	...do	Barker and Brock (1965)	In small bodies; possibly is a foliated variety of ~1,400-m.y. age group.	Brock and Barker (1972).
Central City Granite	Cent. Front Range	Underhill (1906)	Obsolete; in small concordant body later assigned to Boulder Creek Granite (Lovering and Goddard, 1950).	Sims (1964).
Cripple Creek Augen Gneiss.	S. Front Range	Hutchinson and Hedge (1967); Hutchinson (1972).	Invalid; name preoccupied	Scott and others (1976).
Cross Creek Granite**	Sawatch and Gore Ranges.	Tweto and Lovering (1977).	Batholithic body in northern Sawatch Range and Gore Range; mapped previously as "granite of Cross Creek".	Tweto, Bryant, and Williams (1970); Tweto (1974); Tweto and Lovering (1977).
Denny Creek Granodiorite**.	Sawatch and Mosquito Ranges.	Barker and Brock (1965)	Batholithic body in central Sawatch and Mosquito Ranges; includes rock in Mosquito Range mapped as Pikes Peak Granite by Stark and Barnes (1935) and as Trout Creek Augen Gneiss by Hutchinson (1972).	Brock and Barker (1972); Scott (1975).
Evans Granite	E.-cent. Front Range	Underhill (1906)	Obsolete; not defined; small area indicated on map is now classed as Boulder Creek Granite.	Sheridan and Marsh (1976).
Glendale Granite	...do	Crawford (1909)	Obsolete; one of areas of pink porphyritic quartz monzonite in Boulder Creek batholith.	Lovering and Goddard (1950); Wrucke and Wilson (1967).
Kroenke Granodiorite**	Sawatch Range	Barker and Brock (1965)	In several bodies in cent. Sawatch Range and adjoining lower slopes of Mosquito Range; trondhjemitic in composition.	Brock and Barker (1972); Barker and others (1974).
Mount Champion Quartz Monzonite.	...do	Howell (1919)	Obsolete; name not used since introduction	Tweto, Moench, and Reed (1976).

Mount Evans Quartz Monzonite or Granodiorite, or Gneiss.	Cent. Front Range	Boos and Aberdeen (1940)	Name abandoned by Boos (1954) in favor of Boulder Creek Granite, but some recent use (Göbel and Hutchinson, 1971; Puffer, 1972).	Lovering and Goddard (1950); Boos (1954).
Overland Mountain Granite.	...do	Bray (1942)	Obsolete; name applied to rock in satellitic pluton of Boulder Creek batholith.	Lovering and Goddard (1950).
Phantom Canyon Augen Gneiss.	S. Front Range	Hutchinson and Hedge (1967); Hutchinson (1972).	Distinction between this unit and Cripple Creek Augen Gneiss not indicated.	Scott and others (1976).
Pitts Meadow Granodiorite**.	Gunnison River	Hansen (1968)	Probably in batholithic body but exposed only in NW part of Black Canyon of Gunnison River.	Hansen (1968); Hansen and (Peterman (1968); Barker and others (1976).
Powderhorn Granite**	...do	Hunter (1925)	Originally, Powderhorn Granite Group; later, reduced in rank (Burbank and others, 1935); on recent maps, application is restricted compared with original usage; age assignment is based on similarities in character and habit to granites dated by Wetherill and Bickford (1965).	Olson (1974); Hedlund and Olson (1975).
Quartz Creek Granite	...do	Aldrich and others (1956)	Invalid; incidental use of name without definition; same rock classified as informal "granite of Woods Gulch" on recent map (Olson, 1976).	Olson (1976); Wetherill and Bickford (1965).
Tenmile Granite**	Needle Mountains	Cross and others (1905)	In moderately large stock; also includes small stocks and dikes formerly assigned to Whitehead Granite (abandoned).	Barker (1969).
Trout Creek Augen Gneiss	Mosquito Range	Hutchinson and Hedge (1967); Hutchinson (1972).	Same rock as Denny Creek Granodiorite, which has priority; name preoccupied.	Scott (1975); Brock and Barker (1972).
Whitehead Granite	Needle Mountains	Cross and others (1905)	Abandoned (Barker, 1969)	Barker (1969).

Granitic rocks and gabbro of ~1,400-m.y. age group (Precambrian Y)

Bear Mountain Granite	Cent. Front Range	Patton (1909)	Obsolete; small pods later assigned to Silver Plume Granite (Lovering, 1935).	Lovering and Goddard (1950).
Cripple Creek Granite** or Quartz Monzonite.**	S. Front Range	Cross and Penrose (1895); Mathews (1900).	In batholithic body	Hutchinson and Hedge (1967); Scott and others (1976).
Curecanti Granite** or *Quartz Monzonite.***	Gunnison River	Hunter (1925)	In irregular pluton and many small bodies; probably present also in Unaweep Canyon in Uncompahgre Plateau.	Hansen (1971); Hansen and Peterman (1968).
Electra Lake Gabbro**	Needle Mountains	Barker (1969)	In pluton about 6 mi^2 (16 km^2) in area	Barker (1969); Bickford and others (1969).
Eolus Granite**	...do	Cross and others (1905).	In two batholithic bodies	Barker (1969); Bickford and others (1969); Silver and Barker (1968).
Hell Gate Porphyry	Sawatch Range	Stark and Barnes (1932)	Obsolete; one of several facies of St. Kevin Granite	Tweto and Pearson (1964); Tweto (1974).
Indian Creek Granite	Cent. Front Range	Boos and Aberdeen (1940	Abandoned by Boos (1954) in favor of Silver Plume Granite, but some recent use (Puffer, 1972).	Bryant (1974).
Log Cabin Granite	N. Front Range	Boos and Boos (1933)	Invalid; incidental mention in an abstract; rock is generally referred to as "granite of Log Cabin batholith" or Silver Plume Granite.	Peterman, Hedge, and Braddock (1968).
Longs Peak Granite	...do	Fuller (1924)	Inconsistent usage; in subsequent papers, Fuller (under name M.F. Boos) has variously used for same rock "Longs Peak Granite," "granite of Longs Peak batholith", and "Silver Plume Granite".	Do.
Longs Peak–St. Vrain Granite.	...do	Wahlstrom (1940)	Invalid; incidental mention with no indication of intent to introduce formal name.	Do.
Mount Olympus Granite	...do	Fuller (1924)	Abandoned; generally referred to as "granite of Mount Olympus batholith" or as Silver Plume Granite.	Do.

TABLE 1.—*Classification of Precambrian rock units in Colorado*—Continued

Unit	General area	Original reference	Discussion	Reference for age data or for current treatment in mapping
Granitic rocks and gabbro of ~1,400-m.y. age group (Precambrian Y)—Continued				
San Isabel Granite	Wet Mountains	Boyer (1962)	In small batholith; U-Pb age ~1,400 m.y. (T. W. Stern, oral commun., 1976).	Boyer (1962); Taylor (1974).
Santa Fe Granite	Cent. Front Range	Patton (1909)	Invalid; name preoccupied; in small body later classed as Silver Plume Granite (Lovering, 1935).	Lovering and Goddard (1950).
Sherman Granite**	N. Front Range	Blackwelder (1908)	In batholith that straddles Colorado-Wyoming boundary	Peterman, Hedge, and Braddock (1968); Hills and others (1968).
Silver Plume Granite** or Quartz Monzonite.**	Front Range	Ball (1906)	In several batholiths and many minor bodies; leading example of granites of ~1,400-m.y. age group.	Hutchinson and Hedge (1967); Peterman, Hedge, and Braddock (1968); Stern, Phair, and Newell (1971).
St. Kevin Granite**	Sawatch Range	Tweto and Pearson (1964)	In small batholith and many irregular bodies in north half of Sawatch Range.	Pearson and others (1966); Tweto (1974); Doe and Pearson (1969).
Trail Creek Granite	N. Front Range	Eggler (1968)	Intended to be informal but wording is formal; name is preoccupied and should be replaced; unit is an element of "Virginia Dale ring-dike complex" in Sherman batholith.	Eggler (1968).
Trimble Granite**	Needle Mountains	Cross and others (1905)	In moderately large stock intruded into Eolus Granite	Barker (1969); Bickford and others (1969).
Vernal Mesa Quartz Monzonite**	Gunnison River and Uncompahgre Plateau.	Hunter (1925)	In body of indeterminate size partly exposed in Black Canyon of the Gunnison River, and in batholith in NW Uncompahgre Plateau.	Hansen and Peterman (1968); Hedge and others (1968); Bickford and Cudzilo (1975).
Virginia Dale ring-dike complex.	N. Front Range	Eggler (1968)	Intended as a rock-body and structural term but wording is stratigraphic; should be referred to by some term other than "Complex"; feature consists in large part of two facies of Sherman Granite (Trail Creek and "caprock").	Eggler (1968).

Granitic rocks of ~1,000-m.y. age group (Precambrian Y)				
Mount Rosa Granite**	S. Front Range	Finlay (1916)	Alkalic riebeckite granite in small bodies intrusive into Pikes Peak Granite and other rocks of the composite Pikes Peak batholith.	Gross and Heinrich (1965); Barker and others (1975).
Pikes Peak Granite**	...do	Cross (1894)	Chief rock of the large composite Pikes Peak batholith; name has been applied to many different compositional facies and intrusive bodies within the batholith but properly should be restricted to the coarse-grained granite, or rank changed.	Hedge (1970); Barker and others (1975); Hutchinson (1960, 1972).
Raspberry Mountain Granite.	...do	Mathews (1900)	Invalid; casual remark in footnote	Hutchinson (1972).
Redskin Granite**	...do	Hawley and others (1966)	Granite in stock within composite Pikes Peak batholith	Hawley (1969).
Rosalie Granite	...do	Ball (1906)	Abandoned 1929, but some recent use (Puffer, 1972); Pikes Peak Granite in Rosalie lobe of batholith.	Hedge (1970).
Spring Creek Granite	...do	Cross and Penrose (1895)	Abandoned herein; name not used in several decades; applied to very small area of unusually red granite in Pikes Peak batholith at contact in Cripple Creek district.	Scott and others (1976).
Windy Point Granite**	...do	Finlay (1916)	Late aplitic to porphyritic rock in small bodies cutting Pikes Peak Granite.	Gross and Heinrich (1965); Barker and others (1975).
Granitic rock units of more than one age group				
Front Range Granite Group.	Colorado	Burbank and others (1935)	Abandoned herein; not used since introduction; included all named Precambrian granites in State as of 1935.	All references to granitic rocks above.
Mazatzal Granite	Needle Mountains	Hinds (1936)	Invalid; applied to all granites of Needle Mountains on erroneous assumption that all postdate the Uncompahgre Fm.; name preoccupied.	Barker (1969).
Pikes Peak Group	E.-cent. Front Range	Bray (1942)	Invalid; name preoccupied; group consisted of Boulder Creek and Overland Mountain Granites; no relation to Pikes Peak Granite or batholith, and 100 mi (160 km) distant from Pikes Peak.	Lovering and Goddard (1950).
Sangre de Cristo Granite.	Sangre de Cristo Range.	George (1913)	Invalid; name preoccupied; also obsolete; applied on 1913 geologic map of Colorado to mixture of granites, gabbros, and gneisses in Sangre de Cristo Range.	Scott and Taylor (1974); Taylor, Scott, and Wobus (1975).
Troutdale Granite	Cent. Front Range	Underhill (1906)	Invalid and obsolete; applied to a combination of Boulder Creek and Silver Plume Granites and migmatite.	Sheridan and Marsh (1976); Bryant (1974).

and others, 1968; Hansen and Peterman, 1968; Silver and Barker, 1968; Stern and others, 1971). Age of the rocks parent to the metamorphic rocks is not firmly established but apparently does not greatly exceed the age of metamorphism. Age in the range 1,750–1,820 m.y. has been determined from U-Pb isotopic ratios in zircon in metaigneous rocks in the complex in southwestern Colorado (Silver and Barker, 1968), northern New Mexico (L. T. Silver, in Barker and Friedman, 1974), and central Arizona (Anderson and others, 1971). Rb-Sr ratios indicate that metasedimentary rocks in the complex were not derived in any substantial part from an older crustal source such as the >2,500-m.y. Precambrian age province in Wyoming but were derived from rocks that were of mantle origin no more than 2,000 m.y. ago (Z. E. Peterman, oral commun., 1970). The one exception to these generalizations is the Red Creek Quartzite, which in Colorado occupies a very small area at the Utah border in the Uinta Mountains (fig. 1). This unit has a minimum age of 2,320 m.y. (Hansen, 1965), and it probably is part of the >2,500-m.y. age province of Wyoming.

Many names have been applied to elements of the pre-1,700-m.y. metamorphic complex in Colorado (table 1), but only a few have survived the test of usage after introduction. In the Needle Mountains—isolated from other exposures of Precambrian rocks—the Vallecito Conglomerate, Irving Formation, and Twilight Gneiss are in stratigraphic sequence upward (Barker, 1969), and these long-established names remain in use. Elsewhere, the tendency in recent decades has been to forego formal names and to map on the basis of lithic units in the metamorphic complex. Two names that were widely applied in the past, Idaho Springs Formation and Swandyke Hornblende Gneiss, are falling or have fallen into disuse for two principal reasons: (1) The names have been applied so indiscriminately that they no longer convey any stratigraphic relationships but are only ambiguous synonyms for, respectively, the biotitic and the hornblendic gneisses, and (2) neither unit is of the proper rank either to serve any useful purpose in mapping or to serve as a collective term for diverse rocks that are untold miles in thickness. Additionally, neither unit embraces the great bodies of felsic gneiss now recognized to be metavolcanic and subvolcanic intrusive and to be interbedded with the other gneisses. The felsic gneiss was formerly thought to be plutonic quartz monzonite intruded into Idaho Springs and Swandyke.

For reasons detailed in table 1, the following names applied in places to parts of the pre-1,700-m.y. metamorphic complex are herein abandoned:

Gunnison River Series
Needle Mountains Group
River Portal Mica Schist
Salida Schists
Swandyke Hornblende Gneiss
Womack Gneiss

SEDIMENTARY ROCKS YOUNGER THAN 1,700 M.Y.

The two units of sedimentary rocks younger than 1,700 m.y.—the Uncompahgre Formation and the Uinta Mountain Group—are straightforward and require little comment. The Uncompahgre Formation (quartzite, slate, and phyllite) is removed from the Needle Mountain Group, which is herein abandoned. The Uncompahgre is bracketed in age between granites dated at 1,460 and 1,720 m.y. (Barker, 1969). It has no known counterpart in Colorado or in New Mexico outside the Needle Mountains. The nearest sedimentary and volcanic unit with which it might be partly contemporaneous is the Texas Gulch Formation in central Arizona (Anderson and others, 1971).

The Uinta Mountain Group is limited in Colorado to the Uinta Mountains and, largely in the subsurface, to a belt extending eastward to about long 107° (Edwards, 1966). The group has not been subdivided in Colorado, where it consists of quartzite and sandstone as much as 24,000 ft (7.3 km) thick (Hansen, 1965). On the basis of studies in Utah, the group is provisionally dated at 950 m.y. near the top and 1,400 m.y. at the base, and it is thus largely contemporaneous with the Belt Supergroup in Montana and Idaho (Crittenden and Peterman, 1975).

AGE GROUPINGS OF IGNEOUS ROCKS

Radiometric dates are now available for all the major types of Precambrian igneous rocks in Colorado and from all parts of the Precambrian terranes except the Sangre de Cristo Range. The dates fall statistically into three populations centered near 1,700, 1,400, and 1,000 m.y. The rocks of each of these age categories have generally distinctive characteristics, and though age determinations serve to corroborate their assignments, most of them are distinguishable on other grounds. In brief, the rocks that are about 1,700 m.y. in age are generally syntectonic in habit, concordant, commonly foliated, and, among the granitoid facies, mainly granodioritic. Rocks that are about 1,400 m.y. in age are in general posttectonic in habit, discordant in some part, unfoliated or only locally foliated, and, among the granitoid facies, mainly quartz monzonitic to granitic in composition. Rocks that are about 1,000 m.y. in age are anorogenic, discordant, unfoliated, and highly differentiated as indicated by the combination of siliceous granites, various syenites, and minor mafic facies.

Formal collective names for the rocks in each of the three age categories do not exist at this time. In the absence of such names, the informal term "age group" is used as a temporary means of identification. If Precambrian time were more finely divided and named than it is at present,

an age-connoting name (comparable, for example, to "Jurassic rocks") could be substituted for "age group." The rocks of each age group were emplaced and crystallized at intervals through certain periods of time, but they do not define geologic time through those periods. Therefore, they do not meet the requirements of chronostratigraphic units.

IGNEOUS ROCKS OF THE ~1,700-M.Y. AGE GROUP

Syntectonic igneous rocks ranging in age from about 1,650 to 1,730 m.y. are present in all the Precambrian terranes of Colorado except the Uinta Mountains. They range in composition from granite to gabbro. Granitoid rocks, principally granodiorite and quartz monzonite, are by far the most abundant. They occur in several batholiths, numerous smaller plutons, and countless small lenticular bodies. The rocks of some of the batholiths and smaller plutons bear formal names; those of many other bodies do not. The mafic rocks, principally gabbro, occur in widely scattered plutons, the largest of which has a diameter of 10 mi (16 km). None of the mafic rocks bear formal names.

The granitic rock generally recognized as most typical of the ~1,700-m.y. age group is the Boulder Creek Granite (or Granodiorite), which has been studied and mapped in considerable detail in the type batholith west of Boulder, Colo. (Lovering and Tweto, 1953; Wells, 1967; Wrucke and Wilson, 1967; Gable, 1972). The rock is also firmly dated at about 1,720 m.y. by both Rb-Sr and U-Pb (zircon) methods (Peterman and others, 1968; Stern and others, 1971; Phair and others, 1971). The name Boulder Creek has been extended beyond the type batholith and its satellites to plutons scattered through the 200-mi (320-km) length of the Front Range (Lovering and Goddard, 1950, pl. 1), and, in informal usage at least, much farther. Considering the uncertainties inherent in long-distance correlation of igneous rocks, the recent practice of referring to rocks far removed from the type batholith as "of Boulder Creek type" or "of Boulder Creek age" is preferable.

The Cross Creek Granite of the Sawatch and Gore Ranges is dated at 1,715 m.y. (C. E. Hedge, written commun., 1973). The Denny Creek Granodiorite of the Sawatch and Mosquito Ranges probably is of a similar age as it is older than the Kroenke Granodiorite, which is dated at 1,700 m.y. (Barker and others, 1974). Granitic plutons on the southwest flank of the Sawatch Range have been dated at 1,650±35 m.y. (Wetherill and Bickford, 1965). This age may be too young; all the rocks are cataclasized and no completely fresh material has yet been found. Gneissic granodiorite in the Uncompahgre Plateau of extreme western Colorado is dated at 1,670 m.y. (Hedge and others, 1968), but this figure is also suspected to be too low (C. E. Hedge, written commun., 1976). However, dates somewhat below 1,700 m.y. are recorded to the south in New Mexico (Fullagar and Shiver, 1973) and to the southwest in Arizona (L. T. Silver, oral commun., 1974).

In the past, granites of the ~1,700-m.y. age group were widely miscorrelated with the much younger Pikes Peak Granite, as discussed in the section "Igneous rocks of ~1,000-m.y. age group."

IGNEOUS ROCKS OF THE ~1,400-M.Y. AGE GROUP

Posttectonic igneous rocks ranging in age from about 1,350 to 1,480 m.y. are widely distributed in Colorado and are especially abundant in the Front Range. They are overwhelmingly of granitic or quartz monzonitic compositions, but alkalic and mafic compositions are also represented. The granitic rocks are in several batholiths and countless smaller bodies. Rocks of several of the batholiths bear formal names (table 1). Only one mafic rock, Electra Lake Gabbro, is formally named.

The rock generally recognized as most typical of the ~1,400-m.y. age group is Silver Plume Granite, the type body of which is an irregular batholith northwest of Silver Plume in the central Front Range. The name Silver Plume has been widely extended from the type batholith, not only in the Front Range but in ranges to the west. However, the very considerable spread in ages of granites of this age group over the State as a whole dictates caution in extending the name beyond the central and northern Front Range.

The Silver Plume Granite is dated in different bodies at 1,390 to 1,450 m.y. (Peterman and others, 1968; Stern and others, 1971). The Sherman Granite, in a large batholith that extends into Colorado from Wyoming, is dated at 1,435 m.y. (C. E. Hedge, written commun., 1976) and is cut by Silver Plume Granite of the Log Cabin batholith (Peterman and others, 1968). The St. Kevin Granite in the Sawatch Range is of about the same age as the Silver Plume. The St. Kevin is dated at 1,470±65 m.y. by the Rb-Sr method and 1,410±40 m.y. by the U-Pb method (Doe and Pearson, 1969). The Vernal Mesa Quartz Monzonite of western Colorado may be somewhat older, being dated at 1,480±40 m.y. by the Rb-Sr method (Hansen and Peterman, 1968). The Eolus Granite, the principal granite of the ~1,400-m.y. age group in the Needle Mountains, is closely dated at 1,466±27 m.y. by the Rb-Sr method (Bickford and others, 1969) and 1,460±20 m.y. by the U-Pb method (Silver and Barker, 1968).

IGNEOUS ROCKS OF THE ~1,000-M.Y. AGE GROUP

Rocks of the Pikes Peak batholith in the southern Front Range compose a ~1,000-m.y. age group. The batholith is composite, and several distinct intrusive units and rock types are distinguished within it. Four of the units or types have formal names (table 1), and several others are distinguished by rock names. Most of the batholith is referred to the Pikes Peak Granite, a term that in past usage has encompassed not only the coarse-grained pink to pale-orange biotite granite characteristic of the batholith but several other varieties of granite, syenite, and granodiorite (Barker and others, 1975; Hutchinson, 1960). The Mount Rosa, Windy

Point, and Redskin Granites are intrusive into the Pikes Peak Granite.

Age of the Pikes Peak Granite and several of its associated rocks is 1,041±13 m.y. as established from a whole-rock Rb-Sr isochron (Hedge, 1970). As shown by intrusive relations, certain rocks of the batholith are older than those represented in the isochron (Barker and others, 1975, fig. 3), and the Mount Rosa, Windy Point, and Redskin Granites are all younger. However, the entire assemblage is interpreted to be cogenetic (Barker and others, 1975) and may have been emplaced within a time span of no more than 20 m.y. (Hedge, 1970).

In the past, the name Pikes Peak was widely misapplied to granites of Boulder Creek type and age, with the result that the Pikes Peak Granite was once classed as the oldest granite in the Front Range (Lovering, 1929). At its south end, the Pikes Peak batholith is in contact with a granodiorite of the Boulder Creek type. For many years, and as late as 1950 (Lovering and Goddard, 1950, pl. 1), the granodiorite was assumed to be a part of the Pikes Peak batholith and, therefore, to be a variety of Pikes Peak Granite. Similarly, north of a satellitic pluton called the Rosalie lobe of the Pikes Peak batholith, granite of Boulder Creek type was assigned by Lovering (1929) to the Pikes Peak. These misassignments led to further misassignments in ranges to the west, where, in several localities, rocks of the ~1,700-m.y. age group were dubbed Pikes Peak Granite (Stark and Barnes, 1935; Stark and others, 1949; Behre, 1953; Dings and Robinson, 1957).

Confusion over the age of the Pikes Peak Granite relative to granites of the ~1,400-m.y. age group began at an early date. Because the Cripple Creek Granite of the ~1,400-m.y. age group is finer grained than the Pikes Peak, it was judged to be the younger by Mathews (1900). On the grounds of being less sheared than granodiorite that was erroneously assumed to be Pikes Peak, the Cripple Creek was also judged to be the younger by L. C. Graton (in Lindgren and Ransome, 1906). Further, Finlay (1916) erroneously assigned fine-grained dike rocks that cut Pikes Peak Granite to the Cripple Creek. In the central and northern Front Range, similar confusion prevailed with respect to the Silver Plume Granite. Because of the misassignment of granitic rocks of the Boulder Creek type to Pikes Peak Granite, the Silver Plume Granite was long interpreted to be younger than the Pikes Peak Granite (Lovering, 1929; Lovering and Goddard, 1939, 1950; Boos and Aberdeen, 1940; Lovering and Tweto, 1953). This interpretation was supported by yet another miscorrelation: On the basis of a general resemblance, the Sherman Granite was correlated with the Pikes Peak, and the Sherman is observed to be cut by Silver Plume Granite as noted under the preceding heading.

For reasons indicated in table 1, the names Spring Creek Granite and Front Range Granite Group are herein abandoned.

DISCUSSION

A need clearly exists for a systematic nomenclature for Precambrian rocks in Colorado. The state of knowledge is now well enough advanced to begin establishment of such a nomenclature. In particular, the three age groups of igneous rocks warrant formal designation. However, a problem exists in adapting them to the Stratigraphic Code as now worded (American Commission on Stratigraphic Nomenclature, 1970). The age groups would logically become formal rock-stratigraphic groups or, conceivably, supergroups. The problem lies in the fact that "a group consists wholly of divisions defined as formations" and a supergroup is "a formal assemblage of related groups or of formations and groups" (Stratigraphic Code, Article 9). The igneous age groups, on the other hand, consist not only of named units (formations) but of numerous unnamed rocks.

The mechanism of assigning group rank to a name used in one area and formation rank to the same name in another area (permitted by the Code, Article 9) would not be a satisfactory solution to the problem because the named and unnamed igneous rocks are intersprinkled throughout the Precambrian terranes. An area as small as a 7½-minute quadrangle might then require two ranks for the same name, and this obviously is not practical.

One of three courses of action would be necessary to fit the age groups into the existing Code:

1. Apply formal names to the unnamed rocks. Considering the great number of names that would be required, this course is hardly practical and is certainly undesirable.

2. Classify all the unnamed rocks of an age group into one of the named units or, possibly, into one of a few newly defined units. This course, akin to hammering a square peg into a round hole, is undesirable because it would equate rocks that might be of different character, mode of occurrence, position in intrusive sequence, or many millions of years apart in age. Much of the confusion in nomenclature and rock sequence that has existed in the past resulted from unwise extension of names.

3. Establish the age groups as formations and reduce the presently named units to rank of members. (The Stratigraphic Code, Article 9, allows a mixture of named and unnamed members in a formation.) This course would not befit the magnitude and diversity of the age groups. Units such as Boulder Creek, Silver Plume, and Pikes Peak are each divisible into units that are logical members or even formations.

A committee within the American Commission on Stratigraphic Nomenclature is currently (1976) examining the question of whether the Stratigraphic Code should be amended to provide more realistically for the stratigraphic problems peculiar to plutonic and metamorphic rocks and characteristic of many Precambrian terranes. Pending the outcome, establishment of a formal nomenclature for the igneous age groups should be deferred. In the interim, it is possible to classify rocks and communicate unambiguously by referring rocks to the informal age groups used here.

The problems with the pre-1,700-m.y. metamorphic complex differ from those with the igneous rocks. Radiometric dating has not been applicable thus far to subdivision of the complex because of the effects of metamorphism and because the analytical uncertainties in age determinations are of the same order as the time span in which the parent rocks of the complex apparently were deposited (~ 50–75 m.y.). Stratigraphic relations in the metamorphic complex are obscured by multiple folding, partial melting and flowage to the point of structural disorganization in some places, differences in metamorphic grade in different areas, large displacements on Precambrian faults of both premetamorphic and postmetamorphic age, and losses of continuity owing to batholithic intrusion. A large amount of the detailed mapping necessary to overcome these obstacles has been accomplished in the last two decades. Though additional mapping is needed, enough has been done to allow the beginning of regional studies to establish a stratigraphic framework within the metamorphic complex. Until such a framework is established in at least major areas of the Precambrian terranes, there is little point in defining additional formal stratigraphic units in the complex. Meanwhile, informal lithic units can continue to serve the needs in mapping and other studies.

Whatever nomenclatures may be established, they are not limited to Colorado. Various units of the Precambrian rocks of Colorado extend across State lines into New Mexico, Wyoming, and Utah.

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