

**Data structure for DI-18: Geologic  
spatial data for the Clifton-Morenci  
area, Greenlee County, Arizona**

**by  
Tim R. Orr and Stephen M. Richard**

Text to accompany DI-18

Arizona Geological Survey  
416 W. Congress, Suite #100, Tucson, Arizona 85701

## INTRODUCTION

This document, modified from Richard and Thieme, 1997, describes the database structure of Arizona Geological Survey DI-18, Geologic spatial data for the Clifton-Morenci area, Greenlee County, Arizona [Ferguson and others, 2000]. DI-18 is a geospatial database containing information about the geology of the Coronado Mountain, Mitchell Peak, Copperplate Gulch, and Clifton 7½-minute quadrangles – the four USGS quadrangles that encompass the Clifton-Morenci mining district.

The purpose of this document is to provide a written description of (1) the procedures used to create the dataset; (2) the structure of the dataset; and (3) the feature codes used to attribute the data. It is assumed that the reader is familiar with the basics of Arc/Info data structure and the use of Arc/Info and ArcView software.

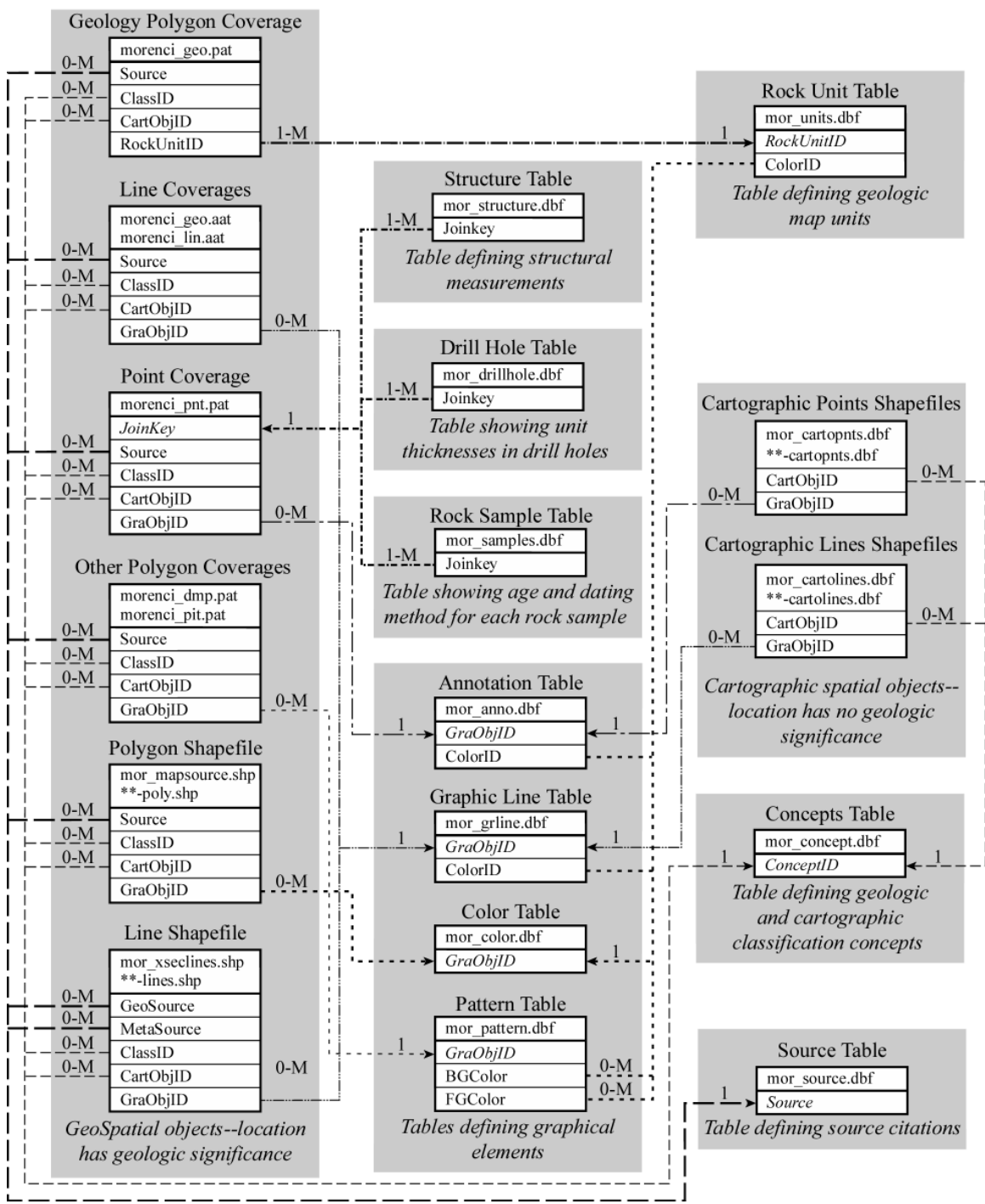
## DIGITIZING PROCEDURE

This dataset was digitized from pencil compilations of geologic field mapping and aerial photo interpretation on paper copies of USGS topographic base maps using Arc/Info v.7.1.1 and a Calcomp Drawingboard II table digitizer. The map projection is Universal Transverse Mercator, zone 12, 1927 North American Datum, and the map units are meters. Arcs were digitized using a weed tolerance of 2.54 meters. Faults were digitized keeping the hanging wall, and thus line symbolization, to the right side of the line as the line was traversed from start point to end point. Editing, edge-matching, and joining of coverages were done using ArcEdit. Attribution of polygons, arcs, and points was done using ArcView GIS v.3.2. Additional shapefiles and tables were created using ArcView GIS v.3.2 and Microsoft Excel 2000. The metadata was written using the MetaData Collection Tool v2.0, an ArcView script written by the NOAA Coastal Services Center, and the TK Metadata Editor by Peter Schweitzer of the USGS in Reston, VA.

## DATA ORGANIZATION

This geographic database is designed to accommodate a geologic map with eight cross sections and is a simplified implementation of a proposed North American standard data model for geologic maps [Johnson and others, 1998]. Attributes have been added to simplify viewing a default layout and querying against a default classification scheme equivalent to the original source map. A data model schema, outlining the coverage, shapefile, and database table relationships for geospatial objects and the map visualization/cartographic layout, is shown in Figure 1.

The geologic and cartographic information in this geographic database is located in numerous Arc/Info coverages and ArcView shapefiles. The **morenci\_geo** coverage contains the lines that represent geologic contacts and faults, and the associated polygons based on those lines that define the outcrop area of map units. The **morenci\_pnt** coverage contains the points associated with structural measurements in the map area. The **morenci\_lin** coverage contains geologic lines that do not define boundaries between rock units, such as concealed faults. The **morenci\_dmp** and **morenci\_pit** coverages contain the polygons that define the areal extent of mine-related rock debris and pits associated with open-pit mining, respectively. The **mor\_mapsource** shapefile contains polygons that show the areal extent of mapping responsibility for each source used to compile the geologic map. The **mor\_xseclines** shapefile contains the lines that mark the location of the geologic cross sections. The **mor\_cartopnts** shapefile contains the points used to locate cartographic features for a default map layout, such as text labels. Last, the **mor\_cartolines** shapefile contains cartographic lines, such as text lead-in lines. Each of these coverages and shapefiles, and the user-defined features included in their feature attribute tables, are summarized in Tables 1 and 2.



**Figure 1.** Map data model showing the data structure of the default geologic and cartographic spatial object classifications and the tables that join to them. Each box represents a data table, and the lines join related fields between these tables. Different line styles indicate joins based on different keys with the arrowhead pointing from the foreign key to the primary key (in italics). Cardinality labels where a line meets a table indicate the number of rows in that table for which the linked field matches a value in the corresponding field of the linked table; ‘1’ = one and only one; ‘1-M’ = at least one; ‘0-M’ = 0 to many.

Each of the eight geologic cross sections , A-A'' through H-H'', contains four shapefiles. The **lines** shapefile contains the lines that represent contacts, faults, and other geologically significant lines. The **poly** shapefile contains the polygons that define the cross section area of the map units. Each cross section also has a **cartolines** shapefile containing cartographic lines, such as text lead-in lines, and a **cartopnts** shapefile containing points used to locate text labels. These shapefiles, and the user-defined features included in their feature attribute tables, are summarized in Tables 1 and 2.

Every spatial object (point, line, or polygon) is uniquely identified by a compound primary key consisting of a source-file identifier (CovID) and a unique identifier within that file (SpObjID). The Arc/Info-assigned UserID's, seemingly good candidates for unique identifiers, are apparently not immutable under build and clean operations on the dataset. Therefore, the 'SpObjID' was added as a user-defined attribute, and the uniqueness constraint must be enforced by the user. Because ArcView, the software used to implement this data model, can not join on a compound key, it has also been necessary to add a user-defined 'JoinKey' attribute for every spatial object in the implementation. Each JoinKey value is a string concatenation of strings representing the numbers in the 'CovID' and 'SpObjID' fields for that record.

**Table 1.** Summary of geologic coverages and shapefiles and their associated database tables. Field definitions are in parentheses. I is an integer field, C is a character field, and the number indicates the width of the field. The attributes in italics can be foreign keys (FK) or primary keys (PK), and are joined with the dBase tables listed using the fields shown in the last column.

Coverage / Shapefile	Type	Attributes	Related tables:	Field joined with:
morenci_geo.pat	Poly	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Unit (C,8) <i>Source</i> (C,50) – FK <i>ClassID</i> (I,16) – FK <i>CartObjID</i> (I,16) – FK <i>RockUnitID</i> (I,16) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_units.dbf	Source ConceptID ConceptID RockUnitID
morenci_geo.aat	Line	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Accuracy (I,8) <i>Source</i> (C,50) – FK <i>ClassID</i> (I,16) – FK <i>CartObjID</i> (I,16) – FK <i>GraObjID</i> (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_grline.dbf	Source ConceptID ConceptID GraObjID

morenci_pnt.pat	Point	CovID (I,16) SpObjID (I,16) JoinKey (C,32) – PK  Accuracy (I,8) Source (C,50) – FK Rotate (I,4) ClassID (I,16) – FK CartObjID (I,16) – FK GraObjID (C,50) – FK	mor_drillhole.dbf mor_samples.dbf mor_structure.dbf  mor_source.dbf  mor_concept.dbf mor_concept.dbf mor_anno.dbf	JoinKey JoinKey JoinKey  Source  ConceptID ConceptID GraObjID
morenci_lin.aat	Line	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Accuracy (I,8) Source (C,50) – FK ClassID (I,16) – FK CartObjID (I,16) – FK GraObjID (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_grline.dbf	Source ConceptID ConceptID GraObjID
morenci_dmp.pat	Poly	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Label (C,8) Source (C,50) – FK ClassID (I,16) – FK CartObjID (I,16) – FK GraObjID (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_pattern.dbf	Source ConceptID ConceptID GraObjID
morenci_pit.pat	Poly	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Label (C,8) Source (C,50) – FK ClassID (I,16) – FK CartObjID (I,16) – FK GraObjID (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_pattern.dbf	Source ConceptID ConceptID GraObjID
mor_mapsource.shp	Poly	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Label (C,8) Source (C,50) – FK ClassID (I,16) – FK CartObjID (I,16) – FK GraObjID (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_pattern.dbf	Source ConceptID ConceptID GraObjID

mor_xseclines.shp	Line	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Accuracy (I,8) XSec_Line (C,8) <i>Source</i> (C,50) – FK <i>ClassID</i> (I,16) – FK <i>CartObjID</i> (I,16) – FK <i>GraObjID</i> (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_grline.dbf	Source ConceptID ConceptID GraObjID
aa-poly.shp bb-poly.shp cc-poly.shp dd-poly.shp ee-poly.shp ff-poly.shp gg-poly.shp hh-poly.shp	Poly	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Unit (C,8) <i>Source</i> (C,50) – FK <i>ClassID</i> (I,16) – FK <i>CartObjID</i> (I,16) – FK <i>RockUnitID</i> (I,16) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_units.dbf	Source ConceptID ConceptID RockUnitID
aa-lines.shp bb-lines.shp cc-lines.shp dd-lines.shp ee-lines.shp ff-lines.shp gg-lines.shp hh-lines.shp	Line	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Accuracy (I,8) Label (C,16) <i>Source</i> (C,50) – FK <i>ClassID</i> (I,16) – FK <i>CartObjID</i> (I,16) – FK <i>GraObjID</i> (C,50) – FK	mor_source.dbf mor_concept.dbf mor_concept.dbf mor_grline.dbf	Source ConceptID ConceptID GraObjID

All geologic points, lines, and polygons have a ‘Source’ attribute that indicates the data source for each object. The ‘Source’ field contains a string identifier derived from the concatenation of the name of the geologist or reference, the map or project name, and the year that the data was collected or compiled. For example, geologic lines in this project compiled by Ferguson and Enders in 1999 are listed as ‘FergusonEndersMorenci99’. In addition to the ‘Source’ attribute, geologic points and lines also have an ‘Accuracy’ attribute that defines the location uncertainty for the point or line in meters. The compound key and the source, plus the accuracy attribute for points and lines, are the minimal set of attributes fundamental to each spatial object.

A number of other attributes are also included in the coverage, shapefile, and dBase data tables to facilitate visualization of the geologic data using a default classification and visualization scheme. The ‘ClassID’ attribute defines the default classification of every spatial object that is geologically significant (depositional contact, cartographic line, structure observation point...), the ‘CartObjID’ attribute classifies graphical objects used to symbolize geologic features in the default visualization (dashed line, font symbol, solid fill...), and the ‘GraObjID’ attribute contains a string describing each graphic object (bedding symbol, 0.35pt solid black line...). ‘ClassID’ and ‘CartObjID’ both refer to records in the ConceptID table (mor\_concept.dbf), and ‘GraObjID’ is used to join to other tables that define the details of the graphical element to be used for symbolization. The ‘CartObjID’ value determines which table the ‘GraObjID’ references. Point

features also have a 'Rotate' attribute that defines the rotation of the graphical element to use for feature symbolization in the ArcView project.

This rotation is positive if the rotation is anticlockwise, and the rotation magnitude depends on the orientation of the symbol in its font definition file.

Different visualizations of the geologic data could be constructed using a different set of spatial objects, possibly originating from different sources, and a user-defined classification of rock-units, contacts, and structures. This would require that 'ClassID', 'CartObjID', 'GraObjID', and 'Rotate' be defined through correlation tables joined to the spatial objects on the compound primary key (JoinKey).

**Table 2.** Summary of cartographic shapefiles and their associated database tables. Field definitions are in parentheses. I is an integer field, C is a character field, and the number indicates the width of the field. The attributes in italics are foreign keys (FK) and are joined with the dBase tables listed using the fields shown in the last column.

Coverage / Shapefile	Type	Attributes	Related tables:	Field joined with:
mor_cartopnts.shp aa-cartopnts.shp bb-cartopnts.shp cc-cartopnts.shp dd-cartopnts.shp ee-cartopnts.shp ff-cartopnts.shp gg-cartopnts.shp hh-cartopnts.shp	Point	CovID (I,16) SpObjID (I,16) JoinKey (C,32) Rotate (I,4) <i>CartObjID</i> (I,16) – FK <i>GraObjID</i> (C,50) – FK	mor_concept.dbf mor_anno.dbf	ConceptID GraObjID
mor_cartolines.shp aa-cartolines.shp bb-cartolines.shp cc-cartolines.shp dd-cartolines.shp ee-cartolines.shp ff-cartolines.shp gg-cartolines.shp hh-cartolines.shp	Line	CovID (I,16) SpObjID (I,16) JoinKey (C,32) <i>CartObjID</i> (I,16) – FK <i>GraObjID</i> (C,50) – FK	mor_concept.dbf mor_grline.dbf	ConceptID GraObjID

## GEOLOGIC COVERAGES AND SHAPEFILES

The coverages and shapefiles below comprise part of the geographic database of the geology of the Clifton-Morenci area. These coverages, and the user-defined features included in their feature attribute tables, are summarized in Table 1.

### Morenci Geology Coverage

The **morenci\_geo** coverage is a polygon and arc coverage that contains the lines representing the contacts, faults, and the map boundary. The polygon topology defined by the lines in this coverage identifies the mapped distribution of rock units.

## Polygon features

The PAT for this coverage contains eight fields.

- COVID: Integer, width 16. Field contains an integer value unique to each coverage and is the first part of the compound primary key for each spatial object. All features in the coverage have the same value. Domain: >0 and <10<sup>16</sup>.
- SPOBJID: Integer, width 16. Field contains an integer value unique to each feature in this coverage and is the second part of the compound primary key for each spatial object. Each feature has a different value. Domain: >0 and <10<sup>16</sup>.
- JOINKEY: Character, width 32. Field contains a string created from the concatenation of the numbers in the 'CovID' and 'SpObjID' fields. Domain: Strings limited by the values in the 'CovID' and 'SpObjID' fields.
- UNIT: Character, width 8. Strings are equivalent to unit labels on the default map layout. This attribute represents the default classification of each polygon to a particular rock unit and is included to make symbolizing and viewing the default map visualization relatively simple. Domain: Strings listed in Table 3.
- SOURCE: Character, width 50. A foreign key joined to the 'Source' field in the Source table. Identifies the source of the geologic information described by this feature. Field contains a concatenation of the author's name (or authors' names), a name that identifies the geographic database that the information is being used in, and the year that the source information was collected or published. Domain: Strings listed in Table 4.
- CLASSID: Integer, width 16. A foreign key joined to the Concept ID table on the 'ConceptID' field. Identifies the concept used to describe each type of geospatial feature on a map. Domain: Values enumerated in Table 5.
- CARTOBJID: Integer, width 16. A foreign key joined to the Concept ID table on the 'ConceptID' field. Identifies the concept used to symbolize each type of cartographic spatial object on a map. Domain: Values are enumerated in Table 6.
- ROCKUNITID: Integer, width 16. A foreign key to the 'RockUnitID' field in the Units table. Identifies the geologic unit associated with the polygon. This plays the role of a classification object ID that is a foreign key to the rock unit definition table. Domain: Values enumerated in Table 3.

**Table 3.** Rock unit table enumerating codes used with the RockUnitID field in the morenci\_geo polygon coverage.

RockUnitID	Unit	Name	Age
1499	R	Stockpiles, mill tailings, road embankments and other facilities	recent
1545	Qt	Talus	Quaternary
1500	Qac	Colluvium	Quaternary
1501	Qal	Alluvium	Quaternary
1502	Qap	Pediment alluvium	Quaternary
1503	Qao	Older alluvium	Quaternary
1504	QTao	Older alluvial deposits	Pliocene
1505	QTgs	Unit of Smuggler Canyon (Gila Group)	Pliocene
1506	QTgg	Unit of Smuggler Canyon, granite-clast facies (Gila Group)	Pliocene
1507	QTgd	Unit of Smuggler Canyon, diorite-clast facies (Gila Group)	Pliocene



1508	Tgbr	Unit of Buzzard Roost Canyon (Gila Group)	Pliocene
1509	Tgbr <sub>cc</sub>	Unit of Buzzard Roost Canyon, Chase Creek facies (Gila Group)	Pliocene
1510	Tgbr <sub>sf</sub>	Unit of Buzzard Roost Canyon, San Francisco facies (Gila Group)	Pliocene
1511	Tgmc	Conglomerate of Midnight Canyon (Gila Group)	Miocene and Pliocene
1512	Tcb	Basaltic conglomerate	Miocene
1513	Tbck	Conglomerate of Bonita Creek	Miocene
1514	Ttt	Rhyolite pyroclastic flows and ash-fall deposits	Miocene
1515	Te	Enebro Mountain Formation, undivided	Miocene
1516	Tet	Enebro Mountain Formation, nonwelded tuff	Miocene
1517	Ter	Enebro Mountain Formation, lava	Miocene
1518	Tei	Enebro Mountain Formation, hypabyssal bodies	Miocene
1519	Tb	Basaltic andesite, undivided	Oligocene to Miocene
1520	Tbs	Mafic volcanoclastic and pyroclastic rocks	Late Oligocene
1521	Tbb	Basaltic andesite scoria and lava breccia	Late Oligocene
1522	Tbi	Hypabyssal bodies of basaltic andesite	Late Oligocene
1523	Tbc	Bloodgood Canyon Tuff	Late Oligocene
1524	Tbl	Lower basaltic andesite	Late Oligocene
1525	Tdc	Crystal-poor ash-flow tuff	Late Oligocene
1526	Tcl	Lower conglomerate	Late Oligocene
1527	Tc	Clifton Tuff	Oligocene
1555	F	Fault zone rocks	Eocene to Miocene
1528	Tbx	Intrusive breccia, undivided	Eocene
1535	Tp	Porphyry, undivided	Eocene
1529	Tpgy	Younger granite porphyry	Eocene
1530	Tpgo	Older granite porphyry, undivided	Eocene
1531	Td	Diabase	Eocene
1532	Tpmq	Quartz monzonite porphyry	Eocene
1533	Tpm	Monzonite porphyry	Eocene
1534	Tpd	Diorite porphyry	Paleocene
1579	TKv	Volcanic and hypabyssal rocks, undivided	Late Cretaceous and Early Tertiary
1536	Kp	Pinkard Formation	Late Cretaceous
1546	Pu	Paleozoic, undivided	Cambrian to Pennsylvanian
1537	MPt	Tule Springs Formation	Mississippian to Pennsylvanian
1538	Mm	Modoc Formation	Mississippian

1539	Dm	Morenci Formation	Devonian
1540	OI	Longfellow Formation	Ordovician
1541	Cc	Coronado Quartzite	Cambrian
1542	Xyg	Granite	Early Proterozoic or Middle Proterozoic
1543	Xygd	Granodiorite	Early Proterozoic or Middle Proterozoic
1544	Xyd	Ferrodiorite	Early Proterozoic or Middle Proterozoic
553	Xp	Pinal Schist, undivided	Early Proterozoic

### Arc features

The AAT for the **morenci\_geo** coverage contains eight fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- ACCURACY: Integer, width 8. Spatial uncertainty in location of a feature, in meters. For example, a value of 10 for a line feature indicates that the geologic entity represented by the line is within 10 meters of the mapped feature. The uncertainty must be greater than the numerical precision of the X,Y coordinates that locate a point (i.e. the accuracy cannot exceed the precision). This value determines the line style that represents the line by using standard solid, dashed and dotted lines. For most existing maps, this length will be based on standard map accuracy, i.e. the geologic entity is located within the width of the line shown on a map for a solid line. A value of -1 indicates that accuracy is not defined, as in the case of cartographic lines or the map neatline. Domain: >numerical precision of data and <10<sup>8</sup>, or -1.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Graphic Line table on the 'GraObjID' field. Defines the style characteristics of each line on the map. Domain: Strings are self-explanatory.

**Table 4.** Source table showing the list of sources used to compile the data in this report.

Source	Citation
LindgrenMorenci05	Lindgren, W., 1905, Description of the Clifton Quadrangle: U.S. Geological Survey, Clifton Folio, scale 1:62,500. (locally with changes required by compilation on new topography)
CunninghamMorenci81	Cunningham, J.E., 1981, Preliminary untitled geologic map of the San Francisco River area north of Clifton, Arizona: Arizona Bureau of Geology and Mineral Technology, Open-file Report: OFR 81-22, scale 1:24,000.

RichterLawrenceMorenci81	Richter, D.H. and Lawrence, V.A., 1981, Geologic map of the Gila-San Francisco Wilderness Study Area, Graham and Greenlee Counties, Arizona: U.S. Geological Survey, Miscellaneous Field Studies, Map MF-1315A, scale 1:62,500.
PreeceandothersMorenci84,99	Preece, R.K., and 26 others, 1984, Geology of the Morenci district as of 4/84: unpublished Phelps Dodge Morenci, Inc. geologic map, scale 1:9,600; updated through 9/99, scale 1:24,000.
PreeceWalkerMorenci84,95	mapping compiled from two sources (PreeceandothersMorenci84,99 / WalkerMorenci95)
PhelpsdodgeMorenci92	Phelps Dodge Morenci, Inc., 1992, Unpublished mapping of the Metcalf pit of the Morenci mine area as of 10/1992
MoreMorenci95	More, S.W., 1995, Project Report: Walker Butte Evaluation, unpubl. Phelps Dodge Exploration Corp. internal report, 10 p. with Figure 2, scale 1:6,000.
PhelpsdodgeMorenci95	Phelps Dodge Morenci, Inc., 1995, Unpublished mapping of the Morenci pit of the Morenci mine area as of 4/1995
WalkerMorenci95	Walker, M.A., 1995, Structural interpretation of the Morenci Mining district, Greenlee, County: unpublished M.Sc. thesis, New Mexico Institute of Mining and Technology, 130 p.
SchroderMorenci96	Schroder, T.J., 1996, Geologic map of the Enebro Mountain Rhyolite: Arizona Geological Survey, Contributed Map: CM-96-A, sheet 1 of 2, scale 1:12,000.
FergusonParkerMorenci98	field mapping by Ferguson, C. A., and Parker, D. B., 1998
EndersParkerMorenci98-99	field mapping by Enders, M. S., and Parker, D. B., 1998-99
FergusonEndersParkerMorenci98-99	field mapping by Ferguson, C. A., Enders, M. S., and Parker, D. B., 1998-99
ChillingworthMorenci99	Chillingworth, G., 1999, Geology of an area north of Morenci, Arizona (Coronado Spring): unpublished. Part II Field Project map, Department of Earth Sciences, University of Cambridge, Cambridge, UK, 47 p. report with map, scale 1:10,000.
FergusonMorenci99	Ferguson, C. A., 1999 air-photo interpretation based on continuation of geology as mapped by Lindgren, W., 1905, and Schroder, T. J., 1996
FergusonEndersMorenci99	field mapping by Ferguson, C. A., and Enders, 1999
JamesMorenci99	James, R., 1999, The geology of part of the northern Clifton Quadrangle, Arizona (Granville Recreation Area): unpublished Part II Field Project map, Department of Earth Sciences, University of Cambridge, Cambridge, UK, scale 1:10,000.
LockMorenci99	Lock, T., 1999, Geologic map of the Chesser Gulch area north of Morenci, Greenlee County, Arizona: unpublished Part II Field Project map, Dept. of Earth Sciences, University of Cambridge, Cambridge, UK, scale 1:10,000.

WarrenMorenci99	Warren, J.M., 1999, The geology of a region north of Morenci, Arizona (Pinal Point): Part II Field Project map, Department of Earth Sciences, University of Cambridge, Cambridge, UK, 31 p. report with map, scale 1:10,000.
WarrenChillingworthMorenci99	mapping compiled from two sources (Warren, J. M., 1999 / Chillingworth, G., 1999)
PhelpsDodgeMorenci99	Phelps Dodge Morenci, Inc., 1999, Unpublished mapping of the Northwest Extension pit of the Morenci mine area as of 8/1999
PhelpsDodgeMorenci99B	Phelps Dodge Morenci, Inc., 1999, Unpublished mapping of areal extent of the Morenci mine pits and mine dumps as of 7/1999
FergusonEndersMorenci00	geologic map and cross sections compiled by Ferguson, C.A., and Enders, M.S., 2000, this document

### **Morenci Point Coverage**

The **morenci\_pnt** coverage is a point coverage locating structural measurements, rock samples, and drill holes. The geographic location of these measurement points is geologically significant.

#### Point features

The PAT for this coverage contains nine fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above. Primary key joined with the Drill Hole table, Rock Sample table, or Structure table on the 'JoinKey' field.
- ACCURACY: see definition above.
- SOURCE: see definition above.
- ROTATE: Integer, width 4. The rotation angle of the feature for the default visualization, measured anticlockwise. Domain: Values range from 0 to  $\pm 360$ .
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Annotation table on the 'GraObjID' field. Defines the symbol type for each point. Domain: Strings are self-explanatory.

### **Morenci Line Coverage**

The **morenci\_lin** coverage is an arc coverage containing concealed faults, fold hinges, and dikes. These line features are placed in a separate coverage because they do not define polygon topology.

#### Arc features

The AAT for this coverage contains eight fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- ACCURACY: see definition above.

- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Graphic Line table on the 'GraObjID' field. Defines the style characteristics of each line on the map. Domain: Strings are self-explanatory.

### Morenci Mine Dump Coverage

The **morenci\_dmp** coverage is a polygon coverage that identifies the areas covered by rock heaps and debris related to mining as of .

#### Polygon features

The PAT for this coverage contains eight fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- LABEL: Character, width 8. This attribute represents the default classification of each polygon to a particular polygon label and is included to make symbolizing and viewing the default map visualization relatively simple. Domain: Strings have not been defined beyond the default classification of 'dump'.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Pattern table on the 'GraObjID' field. Defines the color and pattern characteristics of each polygon in this coverage. Domain: Strings are self-explanatory. The colors are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

**Table 5.** Classification object table enumerating codes used with the 'ClassID' field for coverages and shapefiles in this project.

ClassID	Definition
58	High-angle normal fault
130	Thrust fault
300	Generic crystalloblastic foliation
530	Vein
541	Bedding
543	Igneous flow foliation
544	Eutaxitic foliation
573	Groove or striae in surface
588	Fault orientation (dip direction & dip)
596	Generic high-angle fault with separation unknown
614	Contact of ambiguous nature
615	Dike
620	Depositional contact

621	Intrusive contact
642	Contact placed at boundary of map areas or interpretation volumes
946	Topographic scarp
1988	Fold hinge surface trace of an upright anticline
1994	Fold hinge surface trace of an upright syncline
2009	Sample location
2406	Lithologic map unit
2410	Informal map unit
2411	Formal map unit
2416	Undifferentiated open pit mine
2417	Undifferentiated mine-related rock heap
2418	Drill hole
2419	Cross section line
2423	Intraformational contact
2428	Mapping responsibility area
2432	Earth surface intersection trace
2433	Projected contact
2434	Facies transition
2435	Projected fault
2436	Projected line

**Table 6.** Cartographic object table enumerating codes used with the ‘CartObjID’ field for coverages and shapefiles in this project.

CartObjID	Definition
89	Solid line with filled triangles
91	Dotted line with filled triangles
633	Solid line with hatchures
634	Dashed line with long dashes and hatchures
2392	Font symbol determined by ASCII value
2393	Point text
2396	Text lead-in line
2397	Solid line
2398	Dashed line with long dashes
2399	Dashed line with short dashes
2400	Dotted line
2402	Dashed line with long dashes and queries
2408	Solid fill
2409	Pattern fill
2415	One dash/one dot patterned line
2422	Cross section termination line
2424	Not defined

### **Morenci Mine Pit Coverage**

The **morenci\_pit** coverage is a polygon coverage that identifies the areal extent of pits related to open pit mining as of .

#### Polygon features

The PAT for this coverage contains eight fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- LABEL: Character, width 8. This attribute represents the default classification of each polygon to a particular polygon label and is included to make symbolizing and viewing the default map visualization relatively simple. Domain: Strings have not been defined beyond the default classification of 'pit'.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Pattern table on the 'GraObjID' field. Defines the color and pattern characteristics of each polygon in this coverage. Domain: Strings are self-explanatory. The colors are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

### **Morenci Map Source Shapefile**

The **mor\_mapsource** polygon shapefile identifies the areal extent of the mapping sources used to compile the geologic map of the Clifton-Morenci area as described by this dataset.

#### Polygon features

The shapefile attribute table contains nine fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- LABEL: Character, width 8. This attribute represents the default classification of each polygon to a particular polygon label and is included to make symbolizing and viewing the default map visualization relatively simple. Domain: Strings are abbreviated from strings in the 'Source' field.
- GEOSOURCE: see 'Source' definition above.
- METASOURCE: see definition above, but represents the source of the polygon extent, not the polygon content.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Color table on the 'GraObjID' field. Defines the color used to fill each polygon. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

## Morenci Cross Section Line Shapefile

The **mor\_xseclines** shapefile contains the lines representing the surface trace of geologic cross sections for the Clifton-Morenci map area. These line features are placed in a separate line shapefile because they do not define polygon topology.

### Arc features

The shapefile attribute table contains nine fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- ACCURACY: see definition above.
- XSEC\_LINE: Character, width 8. Strings are interpreted from labels on the default map layout. This attribute represents the categorization of each cross section line or line segment to a default classification. Domain: Strings are self-explanatory.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Graphic Line table on the 'GraObjID' field. Defines the style characteristics of each line on the map. Domain: Strings are self-explanatory.

## Poly Shapefiles

The **aa-poly**, **bb-poly**, **cc-poly**, **dd-poly**, **ee-poly**, **ff-poly**, **gg-poly**, and **hh-poly** shapefiles contain the polygons that identify the mapped distribution of rock units for each cross section.

### Arc features

The shapefile attribute tables contain eight fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- LABEL: Character, width 8. This attribute represents the default classification of each polygon to a particular polygon label and is included to make symbolizing and viewing the default map visualization relatively simple. Domain: Strings have not been defined beyond the default classification of 'pit'.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Pattern table on the 'GraObjID' field. Defines the color and pattern characteristics of each polygon in this coverage. Domain: Strings are self-explanatory. The colors are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

## Lines Shapefiles

The **aa-lines**, **bb-lines**, **cc-lines**, **dd-lines**, **ee-lines**, **ff-lines**, **gg-lines**, and **hh-lines** shapefiles contain the geologic lines for each of the cross sections in the Clifton-Morenci map area.



## Arc features

The shapefile attribute tables contain nine fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- ACCURACY: see definition above.
- LABEL: Character, width 16. Strings are interpreted from labels on the default map layout. Domain: Strings are self-explanatory.
- SOURCE: see definition above.
- CLASSID: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Graphic Line table on the 'GraObjID' field. Defines the style characteristics of each line on the map. Domain: Strings are self-explanatory.

## SHAPEFILES WITH CARTOGRAPHIC LOCATIONS

The shapefiles below contain the cartographic elements for the geologic map of the Clifton-Morenci area. These shapefiles, and the user-defined features included in their feature attribute tables, are summarized in Table 2. The location of points and lines in these files is chosen to provide cartographic clarity. Thus there is no 'ClassID' field, because this field classifies the geological significance of a feature.

### Cartographic Points Shapefile

The **mor\_cartopnts** shapefile contains points that define the location of all text labels, as well as cartographic elements such as fault and fold symbols.

The shapefile attribute table contains six fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- ROTATE: see definition above.
- CARTOBJID: see definition above.
- GRAOBJID: Character, width 50. A foreign key joined to the Annotation table on the 'GraObjID' field. Defines the text label or type of symbol to place at this location. Domain: Strings are self-explanatory.

### Cartographic Lines Shapefile

The **mor\_cartolines** shapefile contains the cartographic lines used as text lead-in lines for map units and other text labels and for cross section termination lines.

The shapefile attribute table contains five fields.

- COVID: see definition above.
- SPOBJID: see definition above.
- JOINKEY: see definition above.
- CARTOBJID: see definition above.

- **GRAOBJID:** Character, width 50. A foreign key joined to the Graphic Line table on the ‘GraObjID’ field. Defines the style characteristics of each line on the map. Domain: Strings are self-explanatory.

## OTHER TABLES

The lookup tables below define the coverage and shapefile codes used in the geographic database of the Clifton-Morenci area. These tables are summarized in Table 7.

### Annotation Table

The annotation table (mor\_anno.dbf) describes the symbolization of all features in the point coverages and point shapefiles.

The table contains nine fields.

- **GRAOBJID:** Character, width 50. Primary key. Unique identifier for each graphical object. Domain: Strings are self-explanatory.
- **TEXTSTRING:** Character, width 254. A string containing the text or the ASCII value of the symbol that will appear on the map. Domain: String are self-explanatory.
- **FONT:** Character, width 50. The name of the font to be used to symbolize the TextString. Domain. Restricted to the fonts available.
- **STYLE:** Character, width 16. The style of the font. Domain: Normal, Bold, Italic, Bold Italic.
- **SPACE:** Floating, width 4. The line spacing. Important when multiple lines of text exist.
- **ALIGN:** Character, width 25. Justification alignment of the text or symbol. Domain: Left, right, center.
- **SIZE:** Floating, width 8. The size of the text or symbol in points for display at the map scale specified by the ‘Scale’ attribute. Domain: >0 and <10<sup>8</sup>.
- **SCALE:** Integer, width 8. The denominator of the map scale. For example, a value of 12000 indicates a map scale of 1:12,000. Domain: >0 and <10<sup>8</sup>.
- **COLORID:** Character, width 50. A foreign key joined to the Color table on the ‘GraObjID’ field. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

**Table 7.** Summary of the database tables. Field definitions are in parentheses. I is an integer field, C is a character field, F is a floating decimal field, and the number indicates field width. Each attribute in italics can be a foreign key (FK) or primary key (PK), and is joined to the coverage, shapefile, or dBase table listed in the ‘Related tables’ column using the field shown in the last column.

Table	Attributes	Related tables:	Field joined with:
mor_anno.dbf	<i>GraObjID</i> (C,50) – PK  TextString (C,254) Font (C,50) Style (C,16) Space (F,4) Align (C,25) Size (F,8) Scale (I,8) <i>ColorID</i> (C,50) - FK	morenci_pnt.pat mor_cartopnts.shp       mor_color.dbf	GraObjID “       ColorID

mor_color.dbf	<i>ColorID</i> (C,50) – PK  Red (I,3) Green (I,3) Blue (I,3)	mor_anno.dbf mor_grline.dbf mor_units.dbf	ColorID “ “
mor_concept.dbf	<i>ConceptID</i> (I,16) – PK  Name (C,64)	morenci_geo.pat morenci_geo.aat morenci_pnt.pat morenci_lin.aat mor_carto.shp mor_cartolines.shp	ClassID/CartObjID “ “ “ “ “
mor_drillhole.dbf	<i>Joinkey</i> (I,16) – FK Drillhole (C,16) QTao(ft) (I,16) QTgs(ft) (I,16) Tgbrcc(ft) (I,16) Tgbrsf(ft) (I,16) Tgmc(ft) (I,16) Total(ft) (I,16)	morenci_pnt.pat	JoinKey
mor_grline.dbf	<i>GraObjID</i> (C,50) – PK  Width (F,8) Size (F,4) Scale (I,8) <i>ColorID</i> (C,50) – FK	morenci_geo.aat morenci_lin.aat mor_cartolines.shp  mor_color.dbf	GraObjID “ “  GraObjID
mor_pattern.dbf	<i>GraObjID</i> (C,50) – PK  <i>BGColor</i> (C,25) – FK <i>FGColor</i> (C,25) – FK Pattern (C,25)	morenci_dmp.pat morenci_pit.pat mor_color.dbf mor_color.dbf	GraObjID “ ColorID ColorID
mor_samples.dbf	<i>JoinKey</i> (C,32) – FK Sample (C,16) Method (C,50) Date(My) (I,16) Error(My) (I,16) AgeLabel (C,25)	morenci_pnt.pat	JoinKey

mor_source.dbf	Source (C,50) – PK  Citation (C,254)	morenci_geo.pat morenci_geo.aat morenci_pnt.pat morenci_lin.aat morenci_dmp.pat morenci_pit.pat mor_mapsource.shp mor_xseclines.shp	Source “ “ “ “ “ “ “
mor_structure.dbf	JoinKey (C,32) – FK Azimuth (I,8) Dip (I,4)	morenci_pnt.pat	JoinKey
mor_units.dbf	RockUnitID (I,16) – PK Unit (C,8) Age (C,64) Name (C,128) SortOrder (I,8) ColorID (C,50) - FK	morenci_geo.pat  mor_color.dbf	RockUnitID  GraObjID

### **Color Table**

The color table (mor\_color.dbf) defines RGB values for colors used in the default symbolization. The RGB values are from the Pantone® [Pantone®, Inc., 1991] color swatch library that comes with Adobe Illustrator®, and represent red, green, and blue values that approximate Pantone® colors for onscreen viewing. Our convention is that the ‘GraObjID’ for a color is a string containing the Pantone® name of the color.

The table contains four fields:

- GRAOBJID: Character, width 50. Primary key. A unique identifier for each color. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.
- RED: Integer, width 3. The red color intensity for screen display of the map unit. Domain: An integer from 0 to 255.
- GREEN: Integer, width 3. The green color intensity for screen display of the map unit. Domain: An integer from 0 to 255.
- BLUE: Integer, width 3. The blue color intensity for screen display of the map unit. Domain: An integer from 0 to 255.

### **Concept ID Table**

The concept ID table (mor\_concept.dbf) identifies the concepts associated with the geologic and cartographic objects in the database. Equivalent to ‘compound objects’ of Johnson et al. [1998].

The table contains two fields.

- CONCEPTID: Integer, width 16. A primary key. Enumerates a numerical code for each concept as specified in the external AZGS concept database. Domain:  $\geq 0$  and  $< 10^{16}$ .
- NAME: Character, width 64. String contains the name of the concept.

### **Drill Hole Table**

The drill hole table (mor\_drillhole.dbf) specifies the drill hole ID and shows the thickness (in feet) of the formations that the drill hole intersects.

The table contains eight fields.

- JOINKEY: see definition above. A foreign key joined to the Morenci Point coverage on the 'JoinKey' field.
- DRILLHOLE: Character, width 16. String contains the drill hole ID.
- QTAO(FT): Integer, width 16. Value is the thickness of the QTao unit in feet as determined by drillhole cuttings.
- QTGS(FT): Integer, width 16. Value is the thickness of the QTgs unit in feet as determined by drillhole cuttings.
- TGBRCC(FT): Integer, width 16. Value is the thickness of the Tgbr<sub>cc</sub> unit in feet as determined by drillhole cuttings.
- TGBRSF(FT): Integer, width 16. Value is the thickness of the Tgbr<sub>sf</sub> unit in feet as determined by drillhole cuttings.
- TGMCC(FT): Integer, width 16. Value is the thickness of the Tgmc unit in feet as determined by drillhole cuttings.
- TOTAL(FT): Integer, width 16. Value is the length of the drill hole.

### **Graphic Line Table**

The graphic line table (mor\_grline.dbf) defines the graphical specifications for line symbols used in the default symbolization.

The table contains four fields.

- GRAOBJID: Character, width 50. Primary key. Unique identifier for each line style. Domain: Strings are self-explanatory.
- WIDTH: Floating, width 8. The thickness of the line in millimeters at a map scale specified by the 'scale' attribute. Domain: >0 and <10<sup>8</sup>.
- SCALE: Integer, width 8. The denominator of the map scale. For example, a value of 12,000 indicates a map scale of 1:12,000. Domain: >0 and <10<sup>8</sup>.
- COLORID: Character, width 50. A foreign key joined to the Color table on the 'GraObjID' field. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

### **Pattern Table**

The pattern table (mor\_pattern.dbf) describes the basic pattern used to symbolize a polygon requiring a pattern fill.

The table contains four fields.

- GRAOBJID: Character, width 50. Primary key. Unique identifier for each pattern fill combination. Our convention is that the string is a concatenation of the fill color Pantone® name, the pattern color Pantone® name, and the pattern type. Domain: Strings are self-explanatory.

- BGCOLOR: Character, width 25. Foreign key to the color table for the background color. This is the color behind the pattern. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.
- FGCOLOR: Character, width 25. Foreign key to the color table for the foreground color of the pattern fill. This is the color applied to the pattern. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.
- PATTERN: Character, width 25. A string with the pattern name that is the foreign key to a pattern definition table. Domain: Strings are self-explanatory.

### **Rock Sample Table**

The rock sample table (mor\_samples.dbf) contains the rock sample ID and describes the age of the rock along with an error bracket and the age dating method used.

The table contains six fields.

- JOINKEY: see definition above. A foreign key joined to the Morenci Point coverage on the 'JoinKey' field.
- SAMPLE: Character, width 16. String is the rock sample ID.
- METHOD: Character, width 50. String is a description of the method used to date the rock samples.
- DATE(MY): Integer, width 16. Value is the age of the rock sample in millions of years.
- ERROR(MY): Integer, width 16. Value is the error bracket for the rock sample age in millions of years.
- AGELABEL: Character, width 25. String is the age label for the rock sample showing a concatenation of the date and error. This string is used to label the rock samples on the map.

### **Source Table**

The source table (mor\_source.dbf) contains the citation information for all geologic objects in the dataset.

The table contains two fields.

- SOURCE: see definition above. Primary key.
- CITATION: Character, width 254. String is a published citation, a concatenation of published citations, a description of the data source, or some combination of these.

### **Structure Table**

The structure table (mor\_structure.dbf) contains the orientation information pertinent to the structural points in the **morenci\_pnt** coverage. In general, many structural measurements, identified by 'ClassID', may be related to one particular spatial object. In this dataset, however, there is only one kind of structural measurement at each point and the 'ClassID' field is not necessary.

The table contains three fields.

- JOINKEY: see definition above. A foreign key joined to the Morenci Point coverage on the 'JoinKey' field.
- AZIMUTH: Integer, width 8. Field contains a value for the attitude or strike of the structural feature. Domain: 0 to  $\pm 360$ .
- DIP: Integer, width 4. Field contains a value for the angle of dip of the structural feature. A value of  $<0$  indicates that this field is not applicable to the feature. Domain: 0 to 90, or  $<0$ .

## Units Table

The units table (mor\_units.dbf) defines the map units. This table is based on a view of the information in an associated rock unit database (under development).

The table contains six fields.

- ROCKUNITID: Integer, width 16. Primary key. The numerical code for each rock unit is specified in the external AZGS rock unit database. Domain: Values are enumerated in Table 2.
- UNIT: Character, width 8. Strings are equivalent to unit labels on source maps. Domain: Values are enumerated in Table 2.
- AGE: Character, width 64. The age of the map unit. Domain: Restricted to ages defined by a standard geologic time scale.
- NAME: Character, width 128. The name of the map unit. Domain: String are self-explanatory.
- SORTORDER: Integer, width 8. An integer used to organize the map units in the order that they will appear on a map explanation. Domain:  $>10^{-8}$  and  $<10^8$ .
- COLORID: Character, width 50. A foreign key joined to the Color table on the 'GraObjID' field. Defines the color used to fill each polygon. Domain: Strings are restricted to the Pantone name for colors in the Pantone® [Pantone®, Inc., 1991] color swatch library.

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