

Standardized Entry and Three-Dimensional Visualization Management of Basic Data for Coal Reserves

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Abstract: With the continuous advancement of intelligent coal mine construction and refined resource management, coal reserve management has imposed higher requirements on the standardized organization of basic data, intuitive expression of spatial objects, rapid query of results, and traceability of management processes. In response to problems such as diverse data sources, inconsistent formats, and the dispersed management of two-dimensional drawings and statistical results, this paper constructs a workflow for standardized data entry and three-dimensional visualization management around data sorting, standardized database entry, two-dimensional drawing extraction, three-dimensional visual expression, and result version management in reserve management. Taking boreholes, boundaries, faults, protective coal pillars, reserve blocks, and parameter tables as the main data objects, the workflow realizes the standardized organization of basic coal reserve data through field unification, coordinate checking, object classification, file archiving, attribute association, and version recording. On this basis, functional modules such as two-dimensional drawing preview, three-dimensional model browsing, result query, and version tracking are designed to form a management loop from data preparation to result display. Application using coal mine data shows that the proposed workflow can improve the standardization and traceability of reserve data management, enhance the spatial expression capability of reserve management objects, and provide basic support for the informatization of coal reserve management.

Keywords: Coal reserves, data standardization, data entry, three-dimensional visualization, information management, result traceability.

1. Introduction

Coal reserve management is an important foundation for mine resource management, mining plan preparation, and production continuity arrangement. It is also a basic component of geological support and resource utilization evaluation in coal mines. Traditional reserve management mainly relies on two-dimensional drawings, reserve ledgers, and manually compiled spreadsheets. Related objects are often stored separately in CAD drawings, Excel tables, geological reports, and model files. This approach remains applicable to routine work, but when data are frequently supplemented, the number of objects increases, and results must be checked continuously, problems such as repeated data sorting, unclear version relationships, separation between drawings and attributes, and poor traceability of statistical results may easily occur.

In recent years, the development of intelligent coal mines and mine informatization has continuously promoted mine business systems from single-purpose data management toward integrated management of data, drawings, models, and results [1-3]. In this context, reserve management is no longer limited to the compilation of final numerical results. It also needs to incorporate reserve objects, basic parameters, drawing sources, result versions, and update processes into a unified management framework, so that reserve results become queryable, verifiable, and traceable [4].

The objects involved in coal reserve management have both spatial and business attributes. On the one hand, boreholes, coal seam boundaries, faults, protective coal pillars, and reserve blocks must be expressed within a unified spatial framework. On the other hand, attributes such as reserve

category, area, thickness, apparent density, statistical results, and update time must remain associated with spatial objects. If management only relies on two-dimensional drawings and scattered tables, it is difficult to intuitively express the spatial relationships among objects, and it is also unfavorable for subsequent result checking and data maintenance [5-7].

This paper focuses on basic data organization and three-dimensional visualization management in coal reserve management. It mainly discusses how multi-source materials can be standardized, classified into databases, jointly displayed in two and three dimensions, and managed by result versioning. The internal algorithms of reserve calculation and the details of model construction are not discussed. Instead, from the perspective of general business management requirements, an implementation workflow is proposed for the preparation, result display, and routine checking of basic coal reserve data, and coal mine data are used for application description [8].

2. Basic Data Types and Management Requirements for Coal Reserves

(1) Basic Data Types

Coal reserve management is an important foundation for mine resource management, mining plan preparation, and production continuity arrangement. It is also a basic component of geological support and resource utilization evaluation in coal mines. Traditional reserve management mainly relies on two-dimensional drawings, reserve ledgers, and manually compiled spreadsheets. Related objects are often stored separately in CAD drawings, Excel tables, geological reports, and model files. This approach remains applicable to routine work, but when data are frequently

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Table 1. Basic data types for coal reserves and their management roles

Data type	Main content	Management role
Coal seam spatial morphology data	Borehole coordinates, stratification information, coal thickness, and related survey data	Support the spatial location and morphological expression of coal seams
Reserve constraint data	Boundaries, faults, protective coal pillars, panel areas, etc.	Define the spatial scope of reserve objects and assist result checking
Reserve calculation unit data	Block boundaries, block numbers, reserve categories, etc.	Support result organization, classified summarization, and drawing-attribute correspondence
Parameter attribute data	Apparent density, thickness, category, remarks, and other fields	Realize association between spatial objects and attribute information
Result management data	Statistical results, version records, reports, and drawing outputs	Support result traceability, result review, and material archiving

(2) Data Preparation and Quality Checking

From the perspective of information management, the requirements for managing basic coal reserve data are mainly reflected in the following aspects. First, data formats need to be unified to avoid inconsistencies in field names, units, and coding rules for the same type of object across different drawings and tables. Second, spatial locations must be verifiable, ensuring that drawing objects, coordinate information, and attribute records correspond correctly. Third, data results must be traceable, including data sources, processing time, responsible personnel, and version status. Fourth, the display method must be intuitive, supporting both rapid preview of two-dimensional drawings and three-

dimensional model browsing and result checking.

In actual data preparation, data problems are often not isolated. They usually arise from the combined effects of graphics, attributes, file versions, and business criteria. For example, a reserve block may be represented only by a boundary line in a CAD drawing, while its number, category, and parameters are recorded in a separate table. If a unified identifier is not established between them, subsequent query and result summarization will become difficult. Therefore, the focus of standardized data entry is not merely to store files in a system, but to establish clear object classification, field specifications, and association rules.

Table 2. Common problems in basic reserve data and processing requirements

Issue type	Main manifestation	Processing requirement
Inconsistent fields	Several names are used for the same meaning, such as block ID, block number, and code	Establish a field dictionary and unify field names, data types, and units
Mixed layers	Faults, blocks, boundaries, and other objects are mixed in the same drawing layer	Separate layers by business object type and retain backup copies of original files
Spatial anomalies	Inconsistent coordinate systems, abnormal local coordinates, or incomplete closed polygons	Conduct coordinate range checks, closure checks, and topology checks
Separation of drawings and attributes	Drawing objects cannot be matched with records in attribute tables	Use a unified object identifier to establish one-to-one or one-to-many associations
Version confusion	Results from multiple time nodes lack descriptions and their usage status is unclear	Record data source, update time, modification description, and result status

(3) Objectives of Standardized Management

The objectives of standardized management can be summarized as follows: each dataset should have a clear source, each object should have a unique identifier, each attribute should follow rules, each result should have a

version, and each display should have a carrier. Data source information clarifies the origin and reliability of the data. Object identifiers ensure that spatial graphics, attribute records, and result files can be associated with each other. Attribute rules unify field meanings and units. Result versions

record the status of each sorting, correction, and output operation. Display carriers support two-dimensional drawing preview, three-dimensional model browsing, and result query. Under these constraints, basic reserve data can be transformed from scattered files into manageable data objects.

3. Workflow for Standardized Basic Data Entry

(1) Overall Entry Workflow

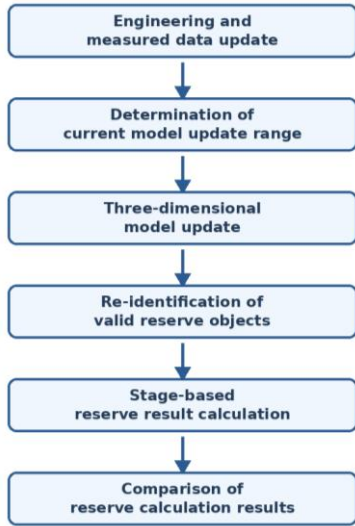


Figure 1. Workflow for standardized entry and visualized management of basic coal reserve data

The standardized entry of basic coal reserve data can be divided into seven steps: collection of original materials, data preprocessing, quality checking, classified entry, attribute

association, result recording, and visual display. The collection stage focuses on the completeness of materials. The preprocessing stage completes format conversion, layer sorting, and field cleaning. The quality-checking stage verifies coordinates, identifiers, closure, and units. The classified-entry stage stores data separately according to object type. The attribute-association stage establishes links between spatial objects and business attributes. The result-recording stage saves statistical tables, screenshots, reports, and version descriptions. The visual-display stage realizes the collaborative management of two-dimensional and three-dimensional information.

(2) Data Preparation and Quality Checking

Before standardized data entry, the original materials should be sorted and checked for quality. For drawing data, layer naming, object closure, line-surface relationships, and coordinate ranges should be checked. For tabular data, field names, units, missing values, duplicate records, and identifier consistency should be checked. For model or result files, the file source, time node, version description, and corresponding business objects should be recorded. These checks can reduce object mismatches and attribute loss in subsequent database entry.

During drawing preparation, reserve blocks, faults, boundaries, protective coal pillars, and other objects should be managed separately by type, avoiding the mixing of different business objects in the same layer or field. For objects with spatial ranges, the boundaries should be closed, topology should be clear, and identifiers should correspond to attribute tables. For boreholes and attribute points, the coordinate system should remain consistent, and obviously abnormal coordinates should be checked.

Table 3. Quality check items before data entry

Check object	Check content	Qualification requirement
CAD drawings	Layer naming, object type, closure, duplicate line segments, and coordinate range	Layer meaning is clear; polygon objects are closed; coordinate range is consistent with the project extent
Borehole data	Hole number, coordinates, elevation, stratification depth, and coal thickness fields	Hole numbers are unique; coordinates show no obvious anomalies; stratification records are complete
Attribute tables	Field names, units, missing values, duplicate records, and identifier correspondence	Fields are unified; units are clear; identifiers can be matched with drawing objects
Result files	File name, result time, corresponding object, and version description	File naming is standardized; version status is clear; paths are traceable
Model files	Model name, spatial extent, object category, and data source	Extent is clear; category is consistent with entered objects; source can be explained

(3) Classified Entry and Attribute Association

After data preparation, classified entry can be conducted according to object type. When spatial objects are entered, object identifiers, object names, data sources, update times, and spatial geometries should be retained. When attribute information is entered, field units, parameter meanings, and corresponding object identifiers should be retained. A unified identifier should be used to establish associations between spatial objects and attribute records, so that users can

simultaneously query object attributes and related results while browsing drawings or three-dimensional models.

For result data in reserve management, version-based management should be adopted. Each data update, drawing correction, or result adjustment should form an independent record, and the update time, update description, and result file path should be stored in the system. This approach can prevent confusion between old and new results and facilitate later result review and process tracking.

Table 4. Suggested fields for associating spatial objects with attribute information

Field category	Recommended fields	Description
Object identifier	object_id, object_name, object_type	Used to uniquely identify spatial objects and their business types
Spatial information	geometry, coordinate_system, extent	Used to store geometry, coordinate system, and spatial extent
Business attributes	block_no, reserve_type, density, thickness	Used to record block number, category, and basic parameters
Source information	data_source, source_file, processor	Used to record source files and processing personnel
Version information	version_no, update_time, update_note, status	Used to record data updates, result status, and descriptions

(4) File Archiving and Version Records

In addition to structured tables and spatial objects, coal reserve materials include a large number of drawings, reports, screenshots, and intermediate result files. For these materials, a directory organization method of “project—data type—time node—result status” can be adopted, while file paths and descriptions are stored in the database. File archiving should avoid naming based only on personal habits. Instead, file names should reflect data type, time, version number, and result status. For example, reserve block drawings, protective coal pillar drawings, parameter summary tables, and result statistics tables should be archived separately and linked to corresponding business objects through version numbers.

Version recording is not equivalent to simple backup. Its role is to explain why a result was updated, which objects were updated, whether the result has been used for statistics, and whether it has historical comparison value. For basic coal reserve data, version records can support result review and can also help quickly locate the affected scope when drawings are adjusted or data are supplemented later.

4. Extraction of Two-Dimensional Drawing Information and Three-Dimensional Visual Expression

(1) Extraction of Two-Dimensional Drawing Information

A large amount of historical data in coal reserve management is stored in the form of two-dimensional CAD drawings. These drawings usually contain block boundaries, fault lines, coal seam boundaries, protective coal pillar ranges, borehole locations, and other information. To realize information-based management, these objects need to be extracted from two-dimensional drawings and transformed into data objects that can be queried, managed, and displayed. During extraction, attention should be paid to layer meanings, object types, identifier relationships, and attribute fields, so that graphical copying does not occur without business semantics.

The key to extracting two-dimensional drawing information is to establish correspondence between graphical objects and reserve business objects. For example, a block boundary is not only a closed polygon object; it must also correspond to a block number, category, area, parameters, and statistical results. A fault object is not only a line feature; it should also correspond to a fault number, property, and influence range. A protective coal pillar is not only a boundary range; it should also correspond to the protected object and management description. Only after graphics and attributes are organized consistently can two-dimensional drawing information further serve three-dimensional display and result management.

Table 5. Correspondence between extracted two-dimensional drawing objects and business attributes

Drawing object	Extracted content	Business attributes to be associated
Block boundary	Closed polygon, boundary line, and block number annotation	Block number, reserve category, area, thickness, apparent density, and result status
Fault object	Fault line, fault number, and extension direction	Fault number, property, throw description, and influence range
Protective coal pillar	Boundary of the protected range and protected object annotation	Protected object, range description, and management status
Mine or panel boundary	Boundary line or polygon and control points	Boundary name, boundary type, data source, and update time
Borehole or attribute point	Point coordinates and borehole or sample number	Hole number, coordinates, elevation, coal seam information, and remarks

(2) Three-Dimensional Visual Expression

After basic data entry is completed, reserve management objects can be expressed in three-dimensional space. The focus of three-dimensional visualization is not to replace the original two-dimensional drawings, but to transform key objects in two-dimensional drawings into more intuitive spatial expressions. This enables users to view the spatial relationships among coal seam boundaries, faults, blocks, and other constraint objects from a stereoscopic perspective. Through three-dimensional display, management personnel can more conveniently check whether object ranges are reasonable, boundary relationships are clear, and result expression is consistent.

For reserve materials that are commonly managed by two-dimensional drawings, three-dimensional expression can also play a role in result integration and auxiliary checking. Two-dimensional drawings are suitable for precise editing and drawing review, while three-dimensional models are suitable for spatial relationship display and result communication. The combination of the two can form a more complete method for reserve information management.

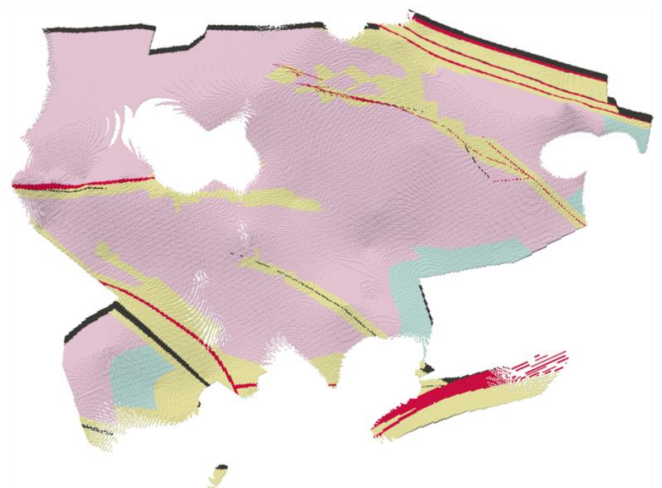


Figure 2. Schematic conversion from two-dimensional drawing information to three-dimensional spatial expression

(3) Platform Function Design

To support basic coal reserve data management and three-dimensional visualization application, platform functions can be divided into five parts: basic data management, drawing and model preview, result query and statistics, version management, and auxiliary output. Basic data management is

mainly responsible for the unified organization of project materials, drawing files, attribute tables, and result files. Drawing and model preview is responsible for two-dimensional drawing browsing, three-dimensional model viewing, and object attribute query. Result query and statistics are used to display existing results by category and export reports. Version management records data states at different time nodes. Auxiliary output is used to generate drawing screenshots, result tables, and summary materials.

Platform design should avoid overemphasizing display

effects while ignoring data management logic. For reserve business, whether data can be queried, whether objects can be traced, and whether results correspond to drawings are often more important than three-dimensional display alone. Therefore, the platform should take data management as the foundation, two-dimensional and three-dimensional preview as auxiliary means, and result recording and version tracking as goals, thereby forming a relatively complete business workflow.

Table 6. Design of main platform functional modules

Functional module	Main function	Corresponding business requirement
Project management	Project creation, material directory maintenance, and data group management	Uniformly organize reserve data from different stages
Data management	Entry of drawings, tables, models, and result files	Realize centralized storage and classified management of materials
Two-dimensional preview	Browsing of CAD drawings, boundaries, blocks, and point/line/polygon objects	Retain traditional drawing review methods
Three-dimensional browsing	Three-dimensional object display, view switching, and object query	Enhance spatial relationship expression and result communication
Result management	Result table query, report export, and screenshot output	Support result review and material archiving
Version management	Update time, update description, and status recording	Support data traceability and process management

(4) Result Query and Version Management

Result query and version management are important links in platform application. Reserve management results usually consist of spatial objects, parameter information, statistical results, and exported files. If only the final table is saved without the corresponding drawing, model state, and processing description, later differences in results are difficult to explain. Therefore, result management should take “object—parameter—result—file—version” as the basic chain, so that each result can be traced to its source object and processing time.

(5) Application Example Using Coal Mine Data

Coal mine data are used in this paper for an application example. The data include borehole materials, reserve drawings, block boundaries, fault objects, protective coal pillar ranges, boundary objects, and related parameter tables. First, the original materials are sorted, and layer naming, field coding, and spatial coordinates are unified. Then, the data are entered separately according to object type, and correspondences between object identifiers and attribute records are established. Finally, two-dimensional drawing preview, three-dimensional model display, and result query are implemented on the platform.

The application process shows that standardized data entry can reduce repeated sorting among drawings, tables, and result files. Two-dimensional preview can retain traditional drawing review habits. Three-dimensional display can enhance the intuitiveness of spatial relationships among reserve objects. Version management can record data updates and result adjustments. Overall, the workflow is suitable for centralized management, result display, and routine checking of coal reserve data.

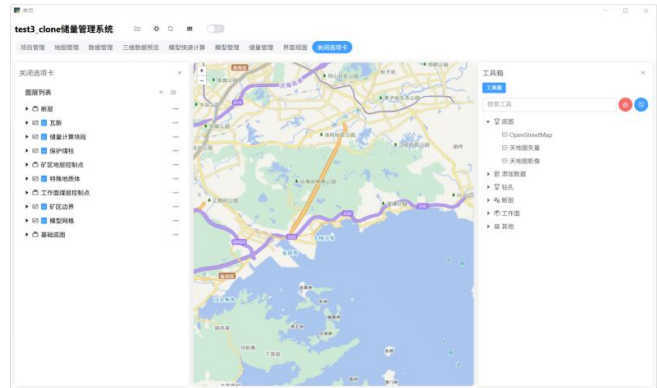


Figure 3. Example interface of coal reserve data management and three-dimensional visualization platform

Table 7. Application workflow and management effects

Application step	Specific work	Management effect
Data preparation	Collect boreholes, drawings, blocks, faults, protective coal pillars, parameter tables, and other materials	Form a unified material list and clarify data sources
Standardized processing	Unify field names, coordinate systems, layer classifications, and object identifiers	Reduce mismatches between drawings and tables
Classified entry	Store spatial data, attribute tables, and result files by object type	Improve data retrieval and maintenance efficiency
Drawing preview	View two-dimensional drawings, layers, and object attributes on the platform	Retain traditional review methods and facilitate manual checking
Three-dimensional display	Display reserve management objects and their spatial relationships in a three-dimensional scene	Enhance spatial expression and result communication capability
Result archiving	Save statistical tables, screenshots, version descriptions, and exported files	Support result traceability and subsequent review

5. Conclusion

From the application perspective, the value of standardized entry and three-dimensional visualization management of basic coal reserve data is mainly reflected in three aspects. First, the data organization method is transformed from scattered file management to object-oriented management, allowing boreholes, blocks, faults, boundaries, protective coal pillars, and result tables to be maintained within a unified framework. Second, the drawing expression method is transformed from a single two-dimensional drawing to coordinated two-dimensional and three-dimensional expression, making the spatial relationships among reserve management objects more intuitive. Third, the result management method is transformed from one-time spreadsheet summarization to version-based recording, giving better traceability to data updates, result corrections, and result review.

At the same time, it should be noted that standardized management of basic data depends to some extent on the quality of original materials. If original CAD drawings lack layer specifications, identifiers are incomplete, or tables contain many missing fields, considerable manual preparation is still needed before database entry. Therefore, in subsequent applications, layer naming specifications, object coding rules, and quality-checking templates should be further improved, so that the whole process from data collection, drawing, and preparation to database entry becomes more standardized.

The workflow discussed in this paper focuses on the implementation of basic data management and visualization application. It does not expand on the internal calculation mechanism of reserve models. For a general journal paper, this topic is more suitable for discussion from the perspective of engineering application, material management, and information display. It can reflect the informatization improvement of coal reserve management while avoiding excessive discussion of complex algorithms and core model details.

And this paper proposes a workflow for standardized entry and visualized management of basic coal reserve data around the requirements of basic data organization and three-dimensional visualization in coal reserve management, and applies it using coal mine data. The main conclusions are as follows: Basic coal reserve data have multi-source, multi-format, and multi-object characteristics. They should be classified into coal seam spatial morphology data, reserve constraint data, reserve calculation unit data, parameter attribute data, and result management data, so as to improve the standardization of data management. Through field unification, coordinate checking, object classification, attribute association, and version recording, corresponding management among two-dimensional drawings, attribute tables, and result files can be realized, reducing repeated

material preparation and difficulty in result traceability. The combination of two-dimensional drawing preview and three-dimensional visual display can retain traditional drawing review methods while enhancing the spatial expression capability of reserve management objects, thereby supporting coal reserve data management, result checking, and information-based display. Platform-based management should take data organization as the foundation, object query and version recording as the core, and two-dimensional/three-dimensional visualization as the expression method. In future work, data quality checking rules, automatic drawing recognition, result report output, and multi-project collaborative management can be further improved according to the characteristics of different coal mine data.

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References

- [1] Wang, G. F., Liu, F., Pang, Y. H., et al. (2019). Intelligent coal mine: Core technical support for high-quality development of the coal industry. *Journal of China Coal Society*, 44(2), 349–357. (in Chinese)
- [2] Ding, E. J., Yu, X., Xia, B., et al. (2022). Development of mine informatization and key technologies of smart mines centered on digital twins. *Journal of China Coal Society*, 47(1), 564–578. (in Chinese)
- [3] An, Y. F. (2021). Design and implementation of a three-dimensional intelligent control system for smart coal mines. *China Coal*, 47(7), 51–61. (in Chinese)
- [4] Wang, S. Y., & Yan, J. P. (2025). Research and application of a dynamic management method for coal resource reserves based on multidimensional cloud GIS. *China Coal*, 51(7), 170–178. (in Chinese)
- [5] Yu, H. (2007). Research on the construction of a three-dimensional visualization coal reserve management system [Master's thesis]. Liaoning Technical University. (in Chinese)
- [6] Yang, B. (2023). Application of three-dimensional geological modeling and visualization technology in solid mineral reserve estimation. *World Nonferrous Metals*, (7), 190–192. (in Chinese)
- [7] Xu, R. Z., & Qi, W. X. (2022). Application of three-dimensional geological modeling and visualization in solid mineral reserve estimation. *World Nonferrous Metals*, (10), 196–198. (in Chinese)
- [8] Wen, G. C., Deng, Y. S., Yu, Y. Q., et al. (2008). Design and implementation of a coal mine information management system. *Mining Research and Development*, (3), 50–52. (in Chinese)