GY461 Computer Mapping & GIS Technology
Digitizing Station Data and Building a Geological Structure Database

Introduction

This document describes the process of converting geological data collected in the field into a digital database that can be used with a GIS to automatically post the station and structure symbols on a digital map with correct orientation, and with dip/plunge values automatically labeled. In this process a relational database is created that is composed of two separate but related database files:

- A database containing attributes that occur once per station, such as latitude or longitude
- A database containing attributes that may occur multiple times at a station point, such as bedding, mineral lineation, etc.

In the following examples several types of application software are used, including database and GIS software. The examples are specific to the applications used, however, the logical steps would be the same regardless of the specific application programs. To follow these examples you would need access to the following applications:

- AutoCAD Map 3.x or higher
- Paradox 5.0 or higher
- Mappro (Freeware)
- Netprog (Freeware)

Make sure that these applications are installed and accessible before starting the below examples. When you have completed the steps outlined below you will have created a flexible database of structure data that is usable with a variety of applications, including GIS. With the GIS you will be able to automatically post the structure data on a digital base map, or select subsets of the data to plot on a stereographic net.

Step 1: Setup for Digitizing

Transfer all station locations to a single quadrangle, preferably one that has been laminated. Inspect the stations to make sure that none of the labels are repeated. At this time you may also want to re-copy the structure orientation data from the field notebook into a tabular format to facilitate data entry. Tape the map onto the digitizer so that it is smooth and stable.

Step 2: Insert Station Blocks

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A block with an attribute must be designed before it can be inserted to mark station locations. Figure 1 is an example of a simple block and attribute combination. The “cross” is simply two lines, whereas the attribute is the text element created with the “DDATTDEF” command. Figure 2 displays the dialog activated by this command, and the information entered to create the attribute. The center of the cross is at coordinates (0,0) because this will be the default insertion point when the block is inserted into another file.

At this point you should calibrate your map to the UTM grid system, and identify this system for your quadrangle. If you have already digitized portions of the quadrangle, be sure to load it first before using the “TABLET” command to calibrate. Assuming that the map is loaded and calibrated, activate the menu sequence “Map > Map Tools > Assign Global Coordinate System”. For this example we will assume that the base map is from northern New Mexico and conforms to the NAD27 datum. Figure 3 displays the dialog activated by the menu choice with appropriate parameters selected from the drop-down list options.

You should now begin to insert the station blocks at the appropriate positions on the map with the digitizer. Position the crosshair of the digitizer puck on the first station. At the AutoCAD command prompt type the “DDINSERT” command (or select it from the INSERT menu). This action activates the Figure 4 dialog. Select the “File” button and traverse the directory structure until the station block that you have designed can be selected. At this point the dialog should appear as in Figure 4. Finish the command as indicated below:

> Insertion point: X scale factor <1> / Corner / XYZ: 50 <CR>
> Y scale factor (default=X): <CR>
> Rotation angle <E>: <CR>
> Enter attribute values
> Station: <Unlabeled>: CA-078

Note that the “<CR>” indicates that the “ENTER” key was pressed. The X and Y scale factor for the block was set to 50, and rotation was 0 degrees. The station label was entered as “CA-078". Continue this procedure until all station data is completely marked by blocks. At this point, the example station map would appear as in Figure 5.

Step 3: Extract the Station Data Locations in a Database Compatible Format

In this step the “DDATTEXT” command will be used to extract the station location data in a format that can be imported into a database or spreadsheet application. For this example we will use Paradox 5.0 because we will eventually add the structure data within that application system. We should store the station locations in the most flexible format possible, i.e. latitude and longitude, therefore we will use the map projection capabilities of ACAD Map to create a map based on latitude and longitude coordinates. Start ACAD Map, create a new drawing, and assign to it a latitude-longitude coordinate system. Figure 6 displays the appearance of the dialog once the coordinate system has been chosen. In this case NAD27 latitude and longitude coordinates in degrees were picked.

The next step creates a file "query" that imports data from the original UTM coordinate file. Figure 7 displays the dialog activated by the "Map > Drawings > Define or Modify Drawing Set". Use the "Attach" button in the dialog to find the original UTM base map and then select the "OK" button. The Dialog should then appear as in Figure 7. Immediately select the menu combination "Map > Query > Define Query", which activates the Figure 8 dialog. Select the "Location" button and then indicate "All" to query all items in the file. Then change the query mode to "draw", and then execute the query by selecting the "Proceed" button. You should then see in the drawing window the same map as you did with the original UTM map, but note that now the coordinate readout will indicate latitude and longitude degrees. Also note that longitude is negative, as it should be in the Western Hemisphere.

Now we are ready to extract the attribute data. This is done with the "DDATTEXT" command, which is the dialog for attribute extraction. Figure 9 displays the dialog activated by this command with relevant data typed into the edit fields. Note that the station blocks were picked with a selection "window" that selected other elements of the drawing. This will not cause a problem, as these extra items are ignored by the extraction command. Also not that the template file is designated as "ST.TXT". This file should be created with a text editor such as "Notepad" before the "DDATTEXT" command is started. The contents of the template file in this example are:

```
STATION    C012000
BL:X       N014007
BL:Y       N014007
```

The first line references the contents of the block attribute tag "STATION" that contains the station label. The label will be exported to a field of 12 characters if the output file format is SDF. The last two items refer to the block x and y coordinates respectively, and will retain 7 decimal places of accuracy. If the extraction format is CDF, text will be surrounded by single quotes, and all items are separated by commas. The first several lines of the extract file will appear as below:

```
'CA078',-105.8284612, 36.2211663
'CA088',-105.8052411, 36.2241399
```

'CA087',-105.8018461, 36.2250935
'CA083',-105.8036644, 36.2279726
'CA082',-105.8047796, 36.2281023
'CA086',-105.8085093, 36.2275716
'CA090',-105.8098672, 36.2271560
'CA074',-105.8111805, 36.2263627
'CA091',-105.8114376, 36.2272240

Note that the coordinates list longitude first since it is the x coordinate. The next step will be to import the CDF extract file into a paradox database table. Activate Paradox and select the menu sequence “File > Working Directory”. Point Paradox to the directory where you want to store the new station database, in this case “C:\PDOXDATA\CU-HILL\”. Now select the menu sequence “Tools > Utilities > Import”. This will activate the dialog displayed in Figure 10. Note that the file type is set to “delimited text”, meaning that all components in the text file are separated by comma delimiters, and that text fields are surrounded by quote characters. When you select the name of the delimited text file, then click on the “OK” button. The next dialog to display is the one in Figure 11. In this dialog you can now specify the name of the new station database table. Because the AutoCAD map attribute extraction process surrounds text items such as the station labels with single quote characters rather than the more standard double quotes, we must click on the “options” button at this point to display the dialog in Figure 12. As indicated in this figure, the text delimiter has been set to a single quote. If you prefer, you could have instead loaded the station location delimited text file into a text editor such as “Wordpad”, and then globally replace all single quotes with double quotes. Regardless of the method, you should now select the “OK” button to create the new database, in this example the file is “CH-ST.DB”, which is a Paradox table. By default the new database will have field names “Field1", “Field2", etc., which will not work for our project. With the menu sequence in Paradox of “File > Open > Table” load this file. You will recognize that the 1^{st} column contains the station labels, the 2^{nd} column contains the longitude in decimal degrees, and the 3^{rd} column contains the latitude value. Select the menu sequence “Table > Restructure Table” do display the dialog in Figure 13. From this dialog you can simply click on the names to re-type them. The “STATION” field should also be marked as a “key” field at this time by double-clicking on that row under the key column. Figure 14 displays the Paradox main window with the new table after these modifications have been made.

The new station database table is a bare minimum table. You may want to add additional fields that store a geologic unit, outcrop description, etc. The important think to remember is that whatever fields you add to this file, the values in the fields should occur only once per station You can use the “Table > Restructure Table” to add additional fields to the database table.

Step 4: Build the Structure Database

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The effective use of a database depends mostly on its design. Our goal is to use the query capabilities of the database application to select structure data that will be used as input into the map projection application MAPPRO. MAPPRO will then take the structure data and create a script file that inserts a structure marker at the position of the station where the data was recorded. MAPPRO understands a variety of common map projection systems, including UTM, therefore it is convenient to store the location data as geodetic latitude and longitude values as we have in the station database. First the structure database file must be designed, and then the data must be entered.

The first step in creating the structure database file is to decide what information must be stored in the file. My experience has suggested the design displayed in Figure 15. The “A” type fields are alpha numeric, whereas the “+” is an auto-incrementing counter that is also a “key” field. The “size” column refers to the character width of each field. You can create a table equivalent to the one in Figure 15 by first selecting “File > New > Table”. Type in the field names and other parameters as in Figure 15. An example of a portion of a completed structure database might look like Figure 16, which is a subset of the northern Alabama Piedmont structure database. You should note the fundamental difference between the structure database and the station database- the same station label may appear more than once in the “STATION” field of the structure database, but should only appear once in the station location database. This is why the “STATION” field cannot be a “key” field in the structure database. In many ways, the relationship between the station and structure databases is the classic “one-to-many” link that any relational database is designed to handle with ease. When all of the structure data is entered you are ready to proceed to the next step: using MAPPRO to automatically insert structure data. One caution before you begin- make sure that you type in the station labels in the structure database exactly as you entered them into the attributes in the AutoCAD Map station blocks. In other words, if you labeled a station block “CA-1" in the AutoCAD file, but then use “ca-01" in the structure database, you will not be able to access the structure data for that station. The database will attempt to link the files on the basis of the label field, so if they don’t match exactly the linkage will fail.

Step 5: Using the MAPPRO application to Automatically Insert Oriented Structure Data

MAPPRO is a useful utility for taking database or spreadsheet query results composed of geodetic coordinates and structure attitude data, and then producing a script file that AutoCAD Map can use to insert oriented structure symbols at the precise location of the station where the data was collected. This saves tremendous amounts of time compared to manually inserting symbols with AutoCAD Map or any other GIS application.

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Before we can use MAPPRO we must first design a Paradox query that links the station and structure databases, and then collects the appropriate type of data, for example, S1 foliation. For the below examples we will use a large station and structure database from the northern Alabama Piedmont, with the goal of inserting S1 data on a specific quadrangle. To begin, start Paradox and make sure that the working directory points to your folder containing the station and structure database files. For this example this will be "\PDOXDATA\NAP\". Select the menu sequence "File > New > Query". This activates the dialog in Figure 17. From the list of table files, select the name of the structure database. In this example, "STRUCT.DB" is the file selected because it contains the structure data that will be accessed by the query. We also need to access the station database because the locations of the stations are only stored in that file. Choose the menu sequence "Query > Add Table" to add the file "STATION.DB" to the query. Figure 18 reflects this change because to will see a row of field names for both tables. Note that the station database has more fields than the previous example, but it serves the same purpose, i.e. it stores the location of each station. The two files need to be linked; to do this select the button bar icon that has to tables in it (the bottom status line will have in it "join tables" when you hover the mouse over the icon). Click in the space below the "STATION" field for both rows in the query. You should see a red "join1" appear in both spaces. Now click on the small white square below the fields in order "Latitude", "Longitude", "Attitude", and "Station" (either one) so that a green "check" mark appears on top of each of those white squares. These are the fields that will be listed when the query is run. The remaining specification is the type of structure we want, in this case S1 foliation. Type in the "S1" in the space below the field name "STRUCTURE", and type in the quadrangle abbreviation "AC" under the "QUAD" field. Run the query by selecting "View > Run Query", which will display results similar to Figure 18. Note that the answer table (i.e. query results) are at the bottom of the figure. Initially the answer table will not display the results in the order needed for MAPPRO: latitude, longitude, structure attitude, and station label. This is easily changed by holding down the left mouse button on the field name in the answer table and "dragging" it the correct position. You should now click on the upper left most latitude. While holding down the "shift" key, move to the lower right-most cell in the answer table. This should "highlight" all values in the table. You can use the "Page Down" key to move to the end of the answer table rapidly if you have a large answer table. When all cells are marked, use the "Edit > Copy" menu sequence to copy this text data to the system clipboard.

The next operation will be pasting the query results into MAPPRO. Start MAPPRO and make sure that the edit window has the focus. Use the menu sequence "Edit > Paste" to insert the query data into the edit window. You should now see four columns of data: Latitude, longitude, S1 attitude, and station label. Do not be concerned if the columns do not always line up; all elements are separated by tabs and will be processed correctly. Through the "Settings" menu you should now set MAPPRO for the data format and for the UTM system:

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- UTM projection with grid zone 16 for this example data
- Set the data format to planar
- Set the Lat/long format to decimal degrees
- Set the script file place the output file in your ACAD directory; set the block name and layer name to “S1".

You are now ready to process the data, so select the menu sequence “Run > Process Edit Window Data”. You should now see a screen similar to Figure 19. At this point the script file has been created and is ready to be imported into AutoCAD Map, however, any block symbols referenced by the script file must first be inserted into the map with the “INSERT” command. For example, because S1 was indicated in MAPPRO as the block symbol, it must be inserted into the quadrangle file before the “SCRIPT” command is run to import the script file output by MAPPRO. Additionally, MAPPRO is intelligent enough to recognize that planar structure with 90 or 0 dip amounts are represented by special symbols that have no dip attribute. If a dip value of 90 is encountered in the data set, a reference to the block “S190" is made. Likewise, a 0 dip would produce a reference to “S10". Because of this possibility, you should also insert these additional two blocks into the AutoCAD file before using the “SCRIPT” command.

Start AutoCAD map and load the base map onto which the structure data will be posted. For this example, since we selected the “AC” quadrangle, we will use the Alexander City quadrangle geologic map (“AC-GEO.DWG”). As mentioned above, make sure the blocks “S1", “S190", and “S10" exist within the drawing file. Now type the command “SCRIPT” at the AutoCAD Map command prompt. You will now see the familiar file open dialog. Find the script file, select the file by clicking on it, and then press the “open” button. You will now see the S1 data plotting on the map. Figure 20 displays the AutoCAD Map screen after the structure data have been imported with a split viewport. Note that the dip attribute is automatically positioned by the script file.

The process for posting linear data is basically the same as for the planar data except that in MAPPRO make sure that you set the format for linear data. Additionally you should be aware that MAPPRO treats fold hinge data (e.g. F1, F2, C1, C2, etc) in a special way. If the characters “Z”, “S”, or “M” follow the linear attitude, MAPPRO will make a reference to “F1Z” for example. This is also true of special orientations, so there may be a reference to “F190S” for example. The “S”, “Z”, and “M” letters refer to the fold symmetry.

Step 6: Selecting Subareas of Structure Data for Stereonet Plots

Once structure data is entered into the structure database file it is possible to use AutoCAD Map to graphically select subareas of structure data, and then copy these selection to the stereonet application NETPROG for plotting on a stereonet projection. This method works by forming links from the station blocks to the external structure database file. The links are based on matching the label attribute in the selected station blocks to the structure database "Station" field value. The database viewer built into AutoCAD Map will allow you to select subareas with a window or window polygon, and you can easily filter the selection so that, for example, only S1 data is accessed. The following steps will use the Millerville quadrangle from the northern Alabama Piedmont as an example file.

Attaching the Database File to the drawing is the first step. Start AutoCAD map and load the quadrangle geologic map. You should note that you do not have to insert the structure symbols before you can complete this step- this procedure depends only on the stations blocks inserted in the drawing, and the structure data entered into the structure database table. Select the menu sequence "Map > Database > Attach Database". The dialog displayed in Figure 21 will pop up on the screen. The correct choice in this example would be the indicated Paradox 5 version database file. Select the "OK" button after this choice is made. You will then see the familiar file open dialog- for this example the file "\PDOXDATA\NAP\STRUCT.DB" was selected. This is the file containing the structure database for the Alabama Piedmont. Figure 22 depicts the file selection dialog. After clicking the "OK" button you will see a dialog requesting a user name and password for opening the database file. Simply click on the "OK" button here to bypass this dialog.

To enable access to the structure database file a "Link path name" (LPN) must be defined. This defines where the file is located, and indicated on which field links will be formed. Select the menu sequence "Map > Database > Define Link Path Name". This will generate the dialog in Figure 23. Note that in this figure you will need to select a table file ("STRUCT.DB") and type in a LPN ("STRUCT"). Also check the "STATION" field as the "key" field. The next procedure is to generate links from the station blocks to the corresponding stations in the structure database. First, turn off all layers except the "STATIONS" layer so that only the station blocks are displayed. Then choose the "Map > Database > Generate Links" option. Fill in the information as in Figure 24, which consists of selecting the ASE type of link and indicating the "ST" block. Leave the other options in the default state. When the "OK" button is clicked, then type "S" to the prompt to allow selection with a window or crossing window around all of the stations. AutoCAD Map will then begin to print the number of links that are forming until the normal command prompt returns. At this point links have been generated from the station blocks to the corresponding structure data on the basis of a common station label.

Next we will open the AutoCAD Map database browser window to "view" the structure data. Select the menu sequence "Map > Database > Browse Database > Link Path Name". This will activate the window in Figure 25 that displays the first several rows in the attached database. Note that all of the data, not just S1, is displayed. We will fix that problem now. Select the menu sequence from the database viewer window of "Records > Filter" to generated the Figure 26 diagram. Modify this dialog to filter in only S1 data as indicated in this figure. When the “OK” button is selected, only S1 data will be displayed in the database viewer. Now we need to graphically select stations that fall on the north limb of the Millerville cross-fold. In the database viewer window select the menu sequence “Highlight > Highlight Data > Select Objects”. This will generate the “select objects:” prompt within the main AutoCAD Map window. Use the “wpoly” option at this prompt to draw a window polygon around desired data. Figure 27 displays the window polygon used to define the data subarea. The database viewer window will then search for the data falling within the polygon, highlighting each row in the structure database. Figure 28 displays the viewer window after the subarea had been defined. Note that the subarea data rows are highlighted by default in yellow, and that a black indicator at left marks the first station found in the database that falls within the subarea.

Start the NETPROG application and use the menu sequence “View > Data Grid” to display a blank data grid window. Now switch over to the database viewer application, drag the mouse over the highlighted structure data, and then use the viewer “Edit > Copy” menu to copy the data to the system clipboard. Immediately switch to the NETPROG data grid and select the menu choice “Edit > Paste” to paste the data into the first column. Repeat this procedure until all of the highlighted structure data is pasted over to the NETPROG data grid window. If there is a large break between highlighted data instead of scrolling you can move the row indicator (black arrow at left) in the database viewer below the last visible highlighted record. Then select the menu sequence in the viewer of “Highlight > Highlight Records > Next Record”. If the indicator does not move then there are no more record highlighted in the database. Although I have not used AutoCAD Map 2000, I have read where that version has an option to display only highlighted records. Obviously, that would allow one to select all highlighted records with one mouse “drag” operation. When all data is in NETPROG, set the plot type and data type, and then generate the stereonet. The stereonet plot of the subarea is displayed in Figure 29.

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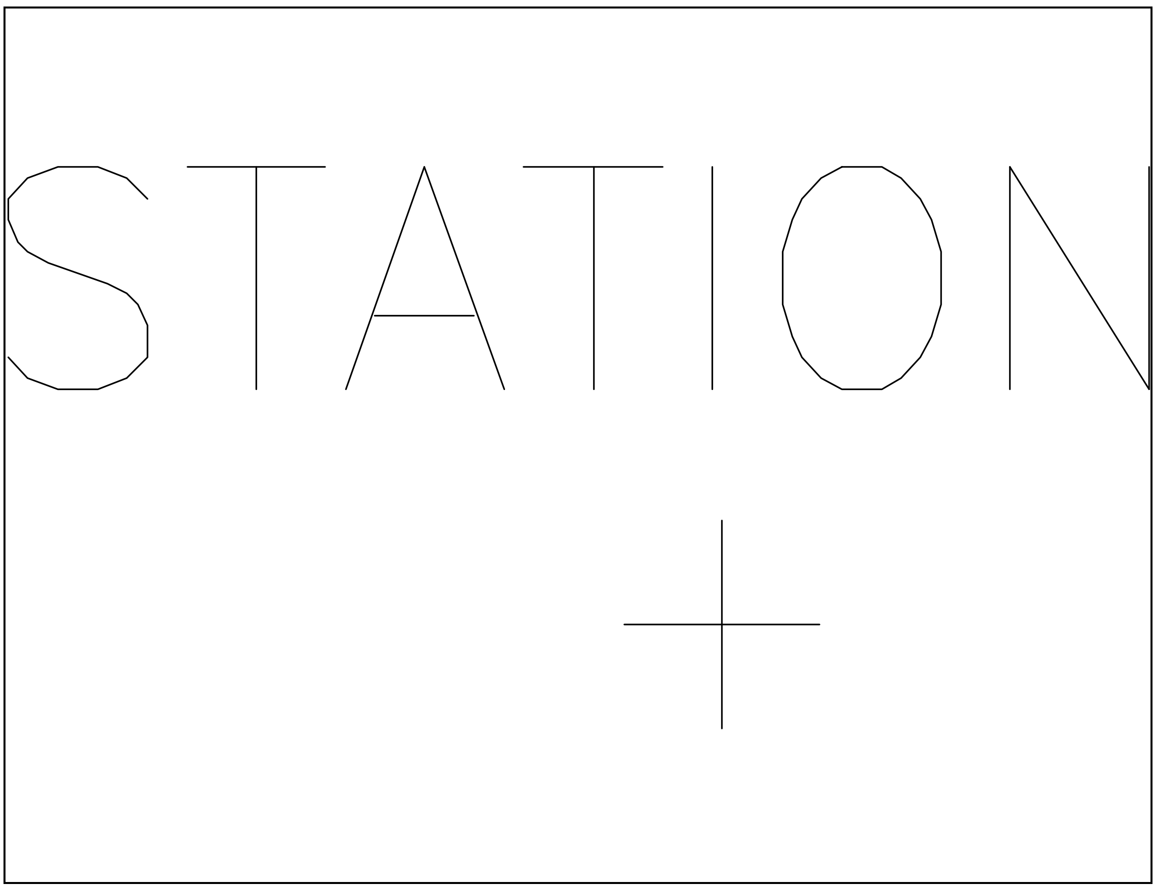

Figure 1: Block with attribute used to mark station locations.

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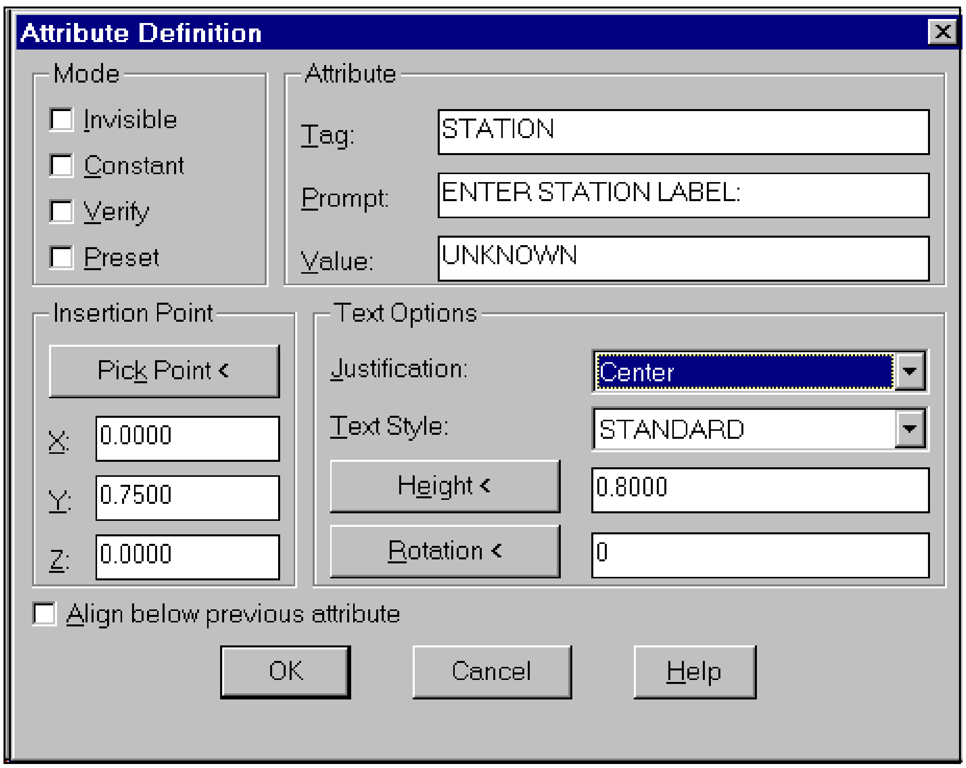

Figure 2: Dialog activated by the DDATTDEF command in AutoCAD Map.

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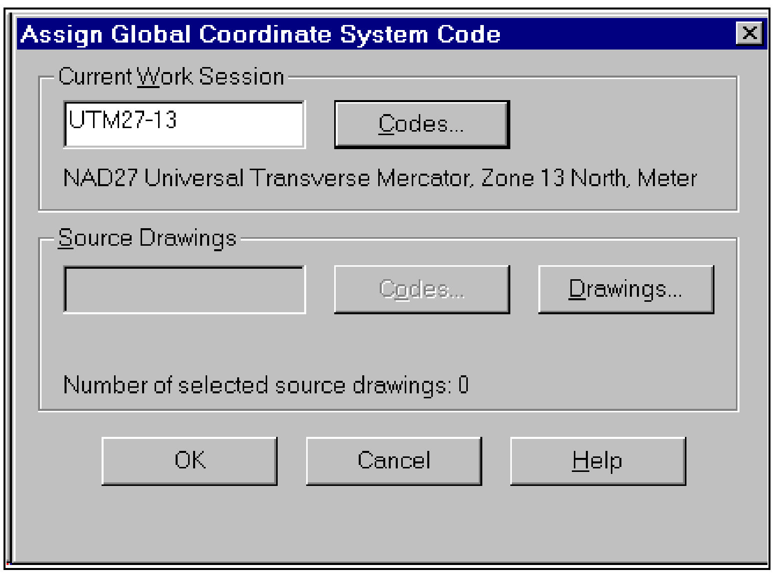

Figure 3: Dialog activated by the "assign global coordinate system" menu selection.

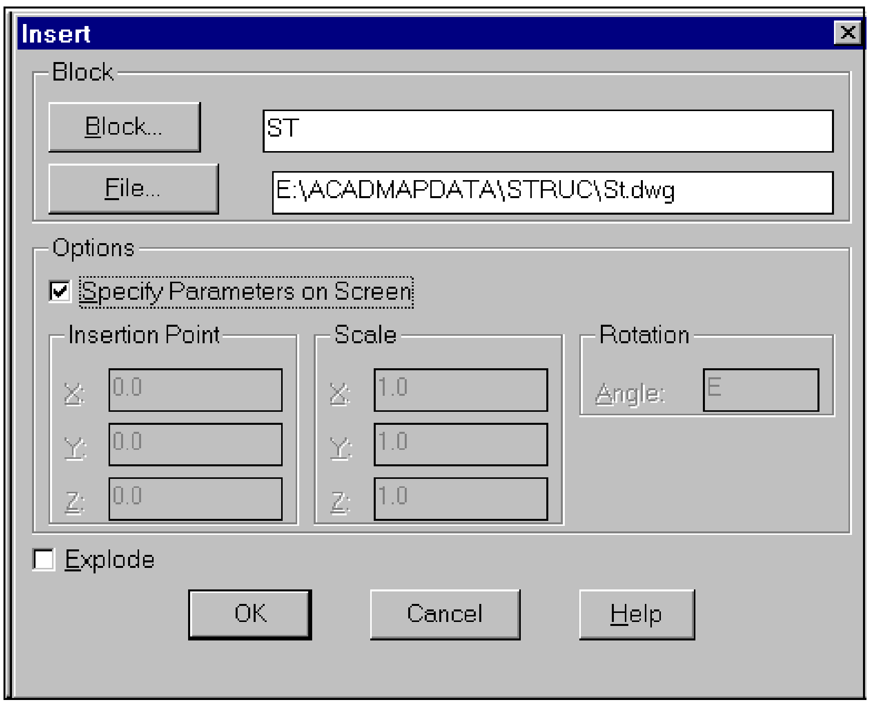

Figure 4: Dialog activated by the “INSERT” command.

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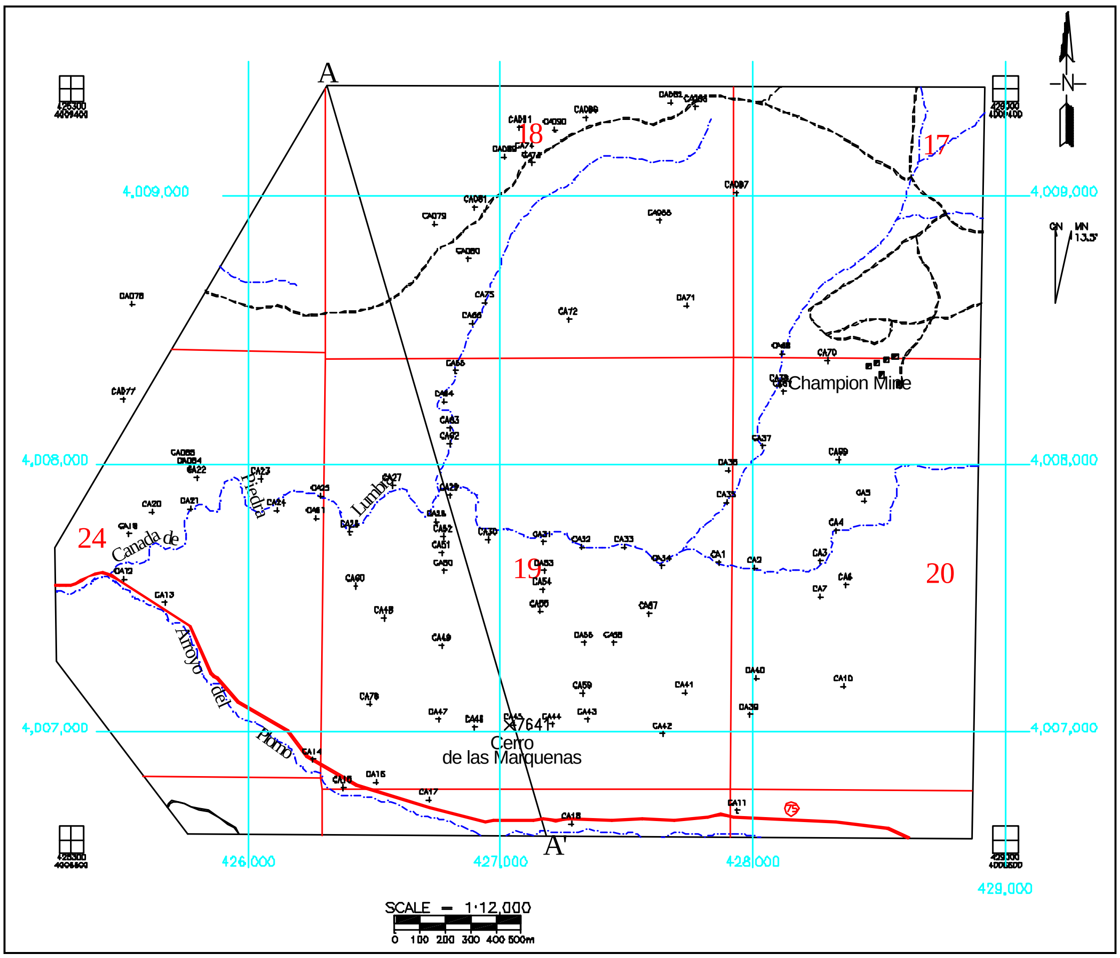

Figure 5: Example of station blocks inserted in AutoCAD digital map.

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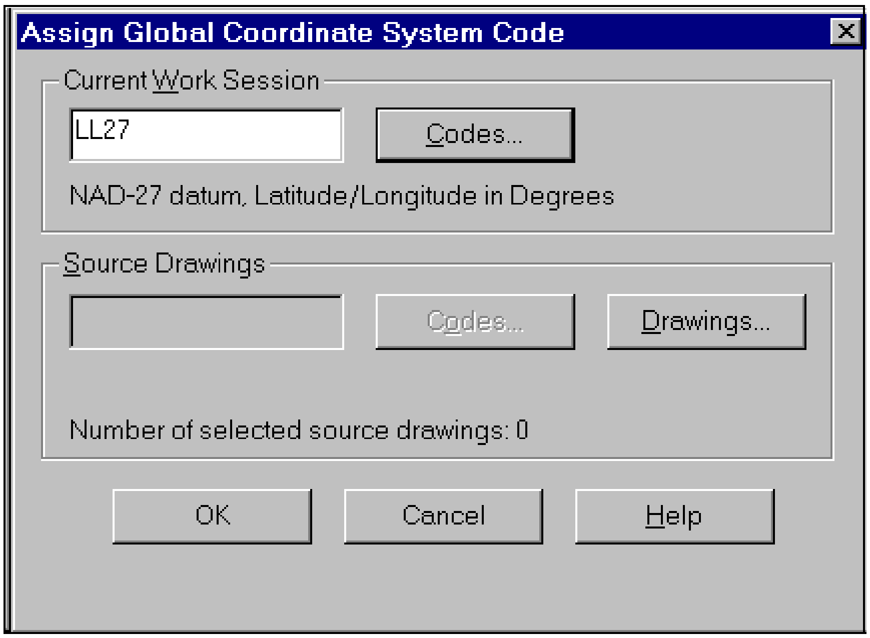

Figure 6: Dialog used to assign a latitude and longitude coordinate system.

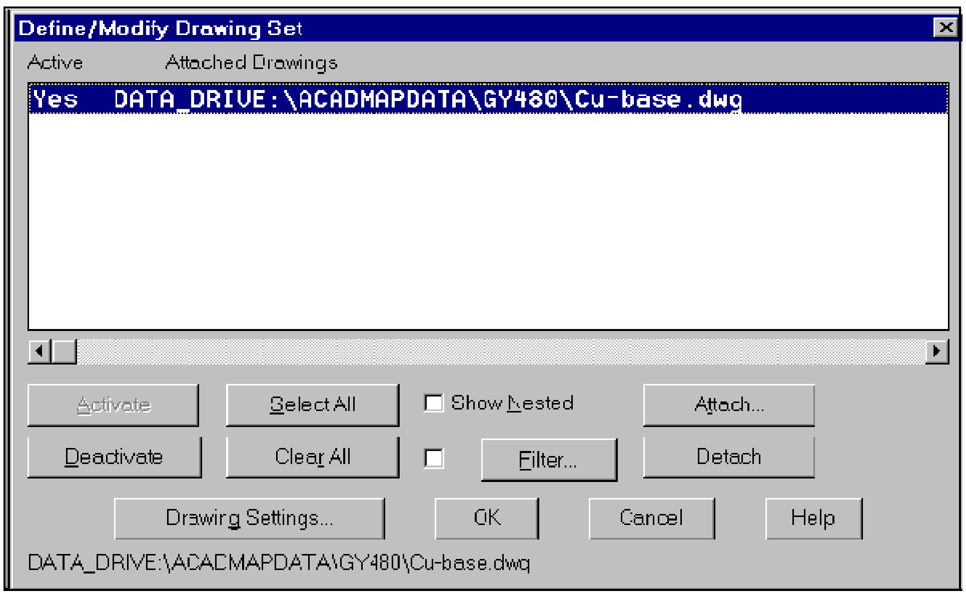

Figure 7: Dialog used to attach the UTM base map to the current drawing.

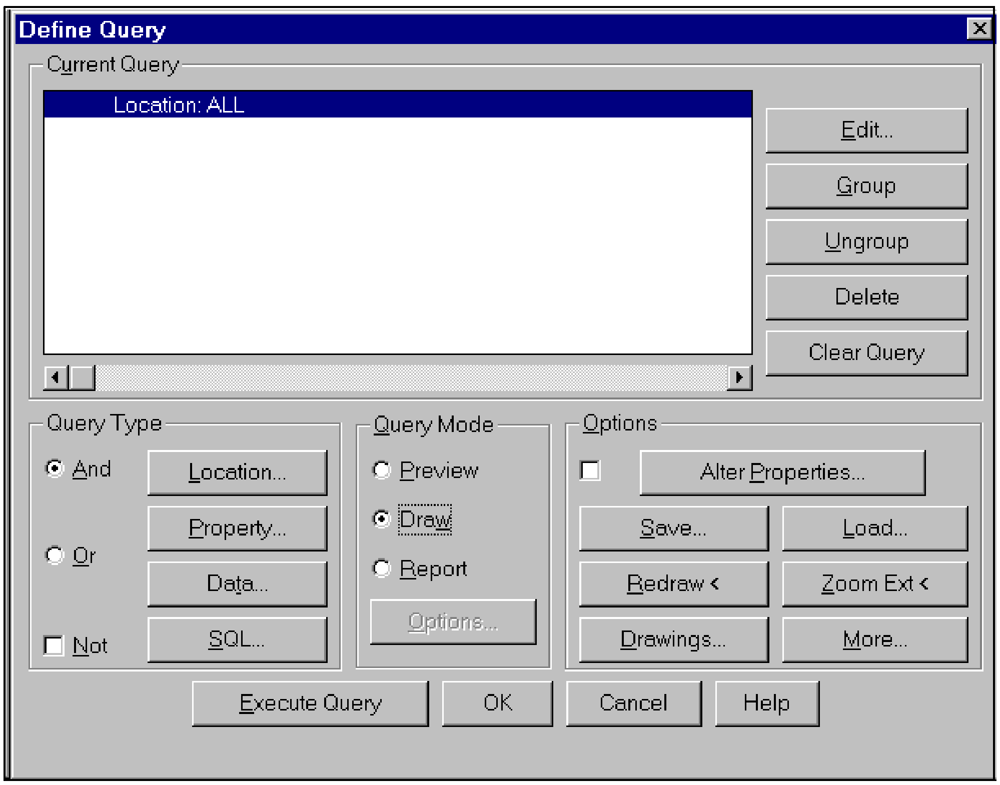

Figure 8: File query dialog used to import the UTM base map into the current latitude and longitude coordinate system.

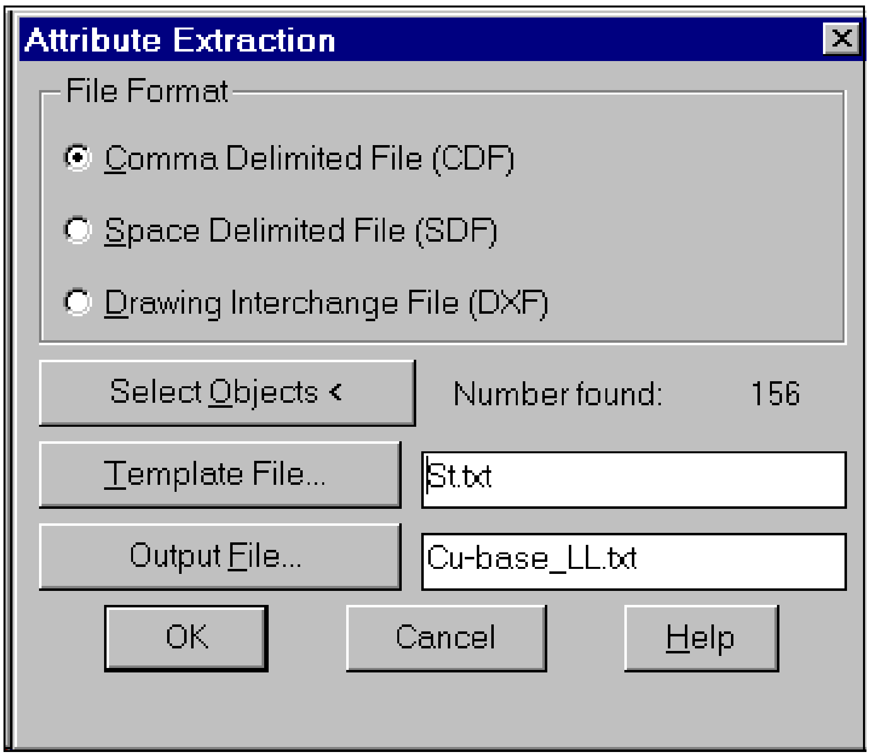

Figure 9: Dialog activated by the "DDATTEXT" AutoCAD command with relevant data inserted.

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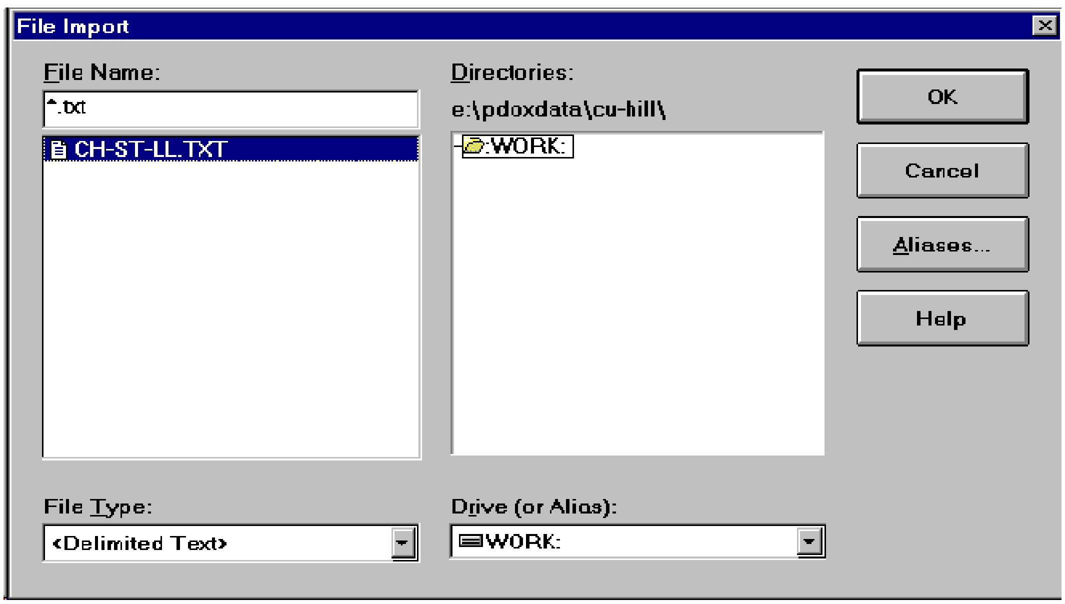

Figure 10: Paradox dialog activated by the menu selection “Tools > Utilities > Import”.

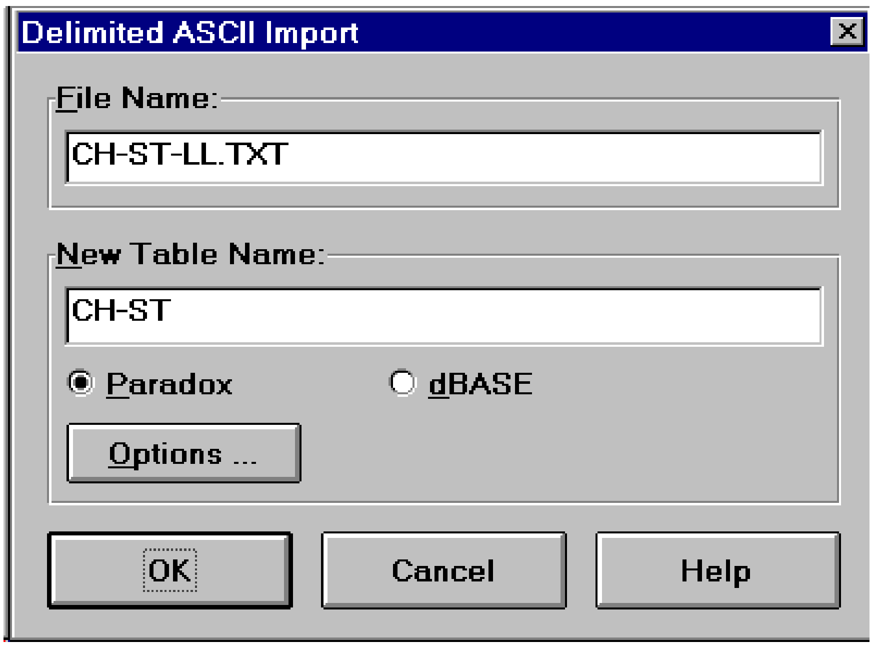

Figure 11: Paradox Dialog for a delimited text file import operation.

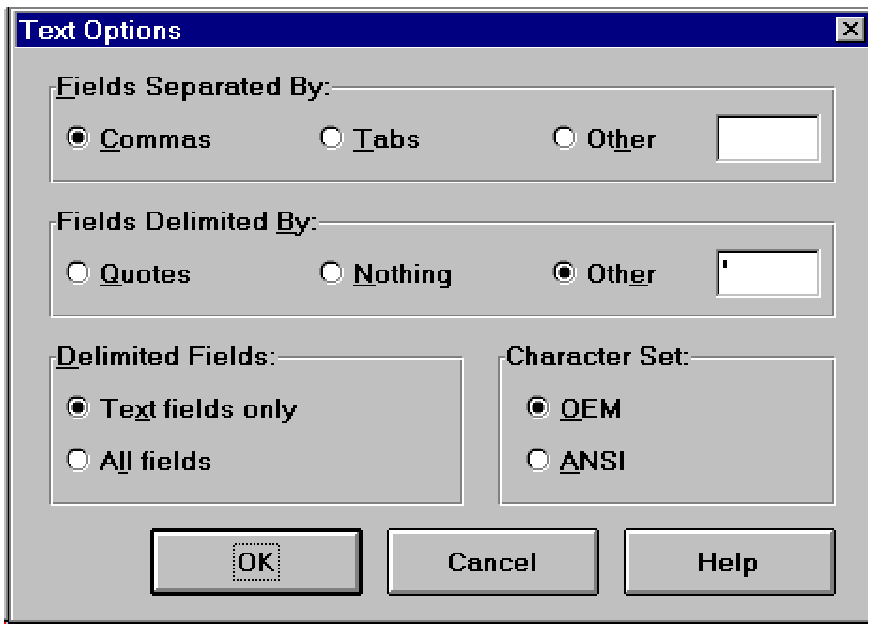

Figure 12: Paradox dialog for setting delimited text import options.

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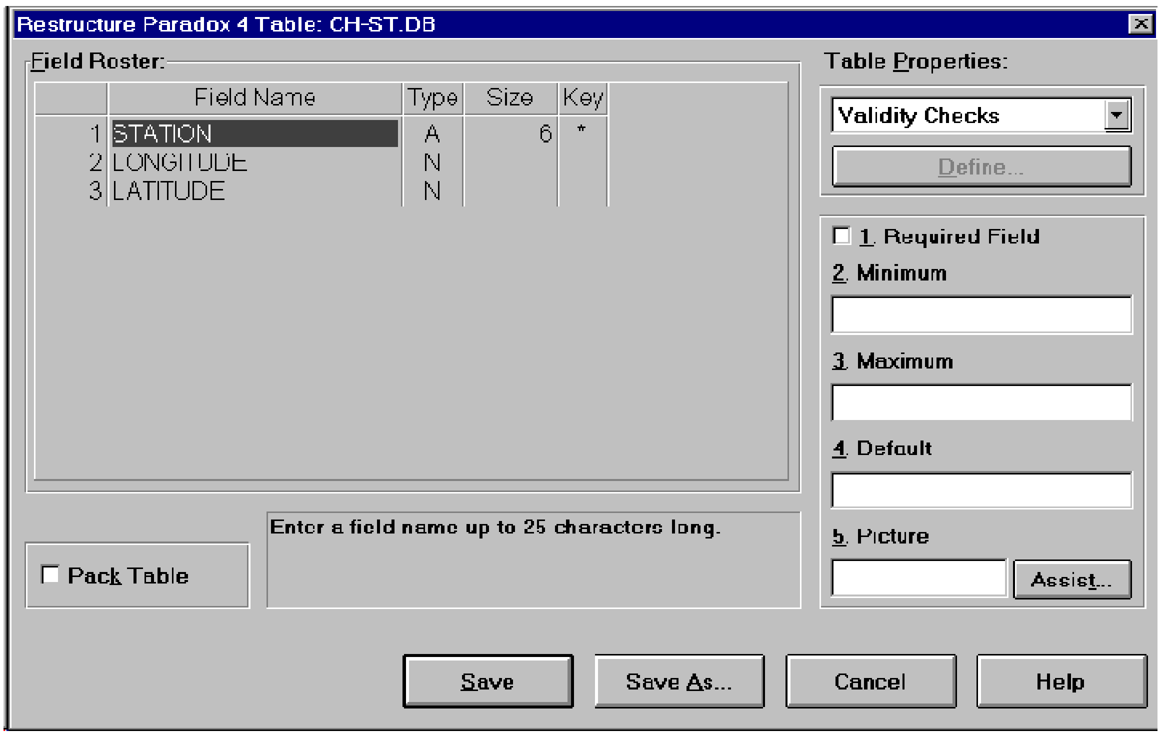

Figure 13: Field restructure dialog activated by the Paradox menu sequence "Table > Restructure Table".

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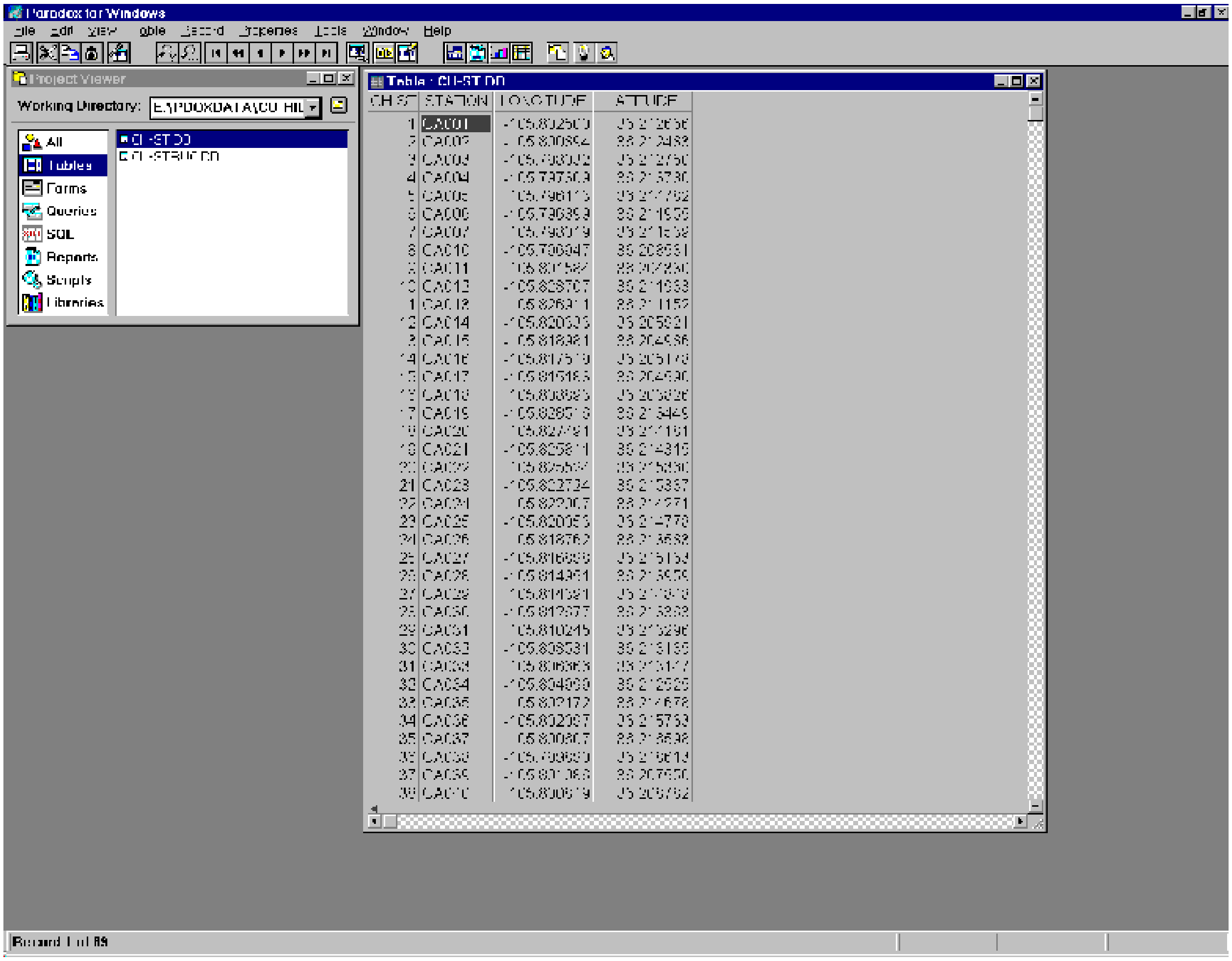

Figure 14: Appearance of the Paradox main window after importing the delimited text file containing the station locations.

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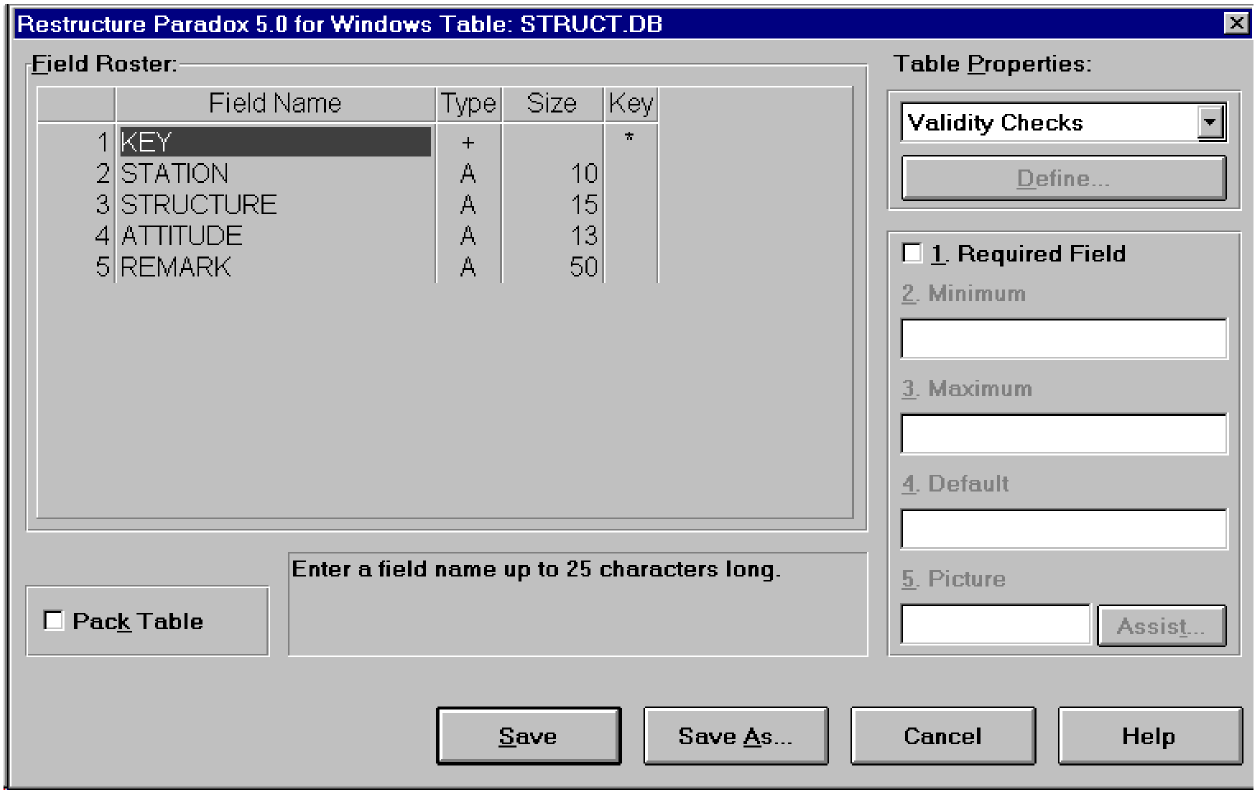

Figure 15: Design of the structure database.

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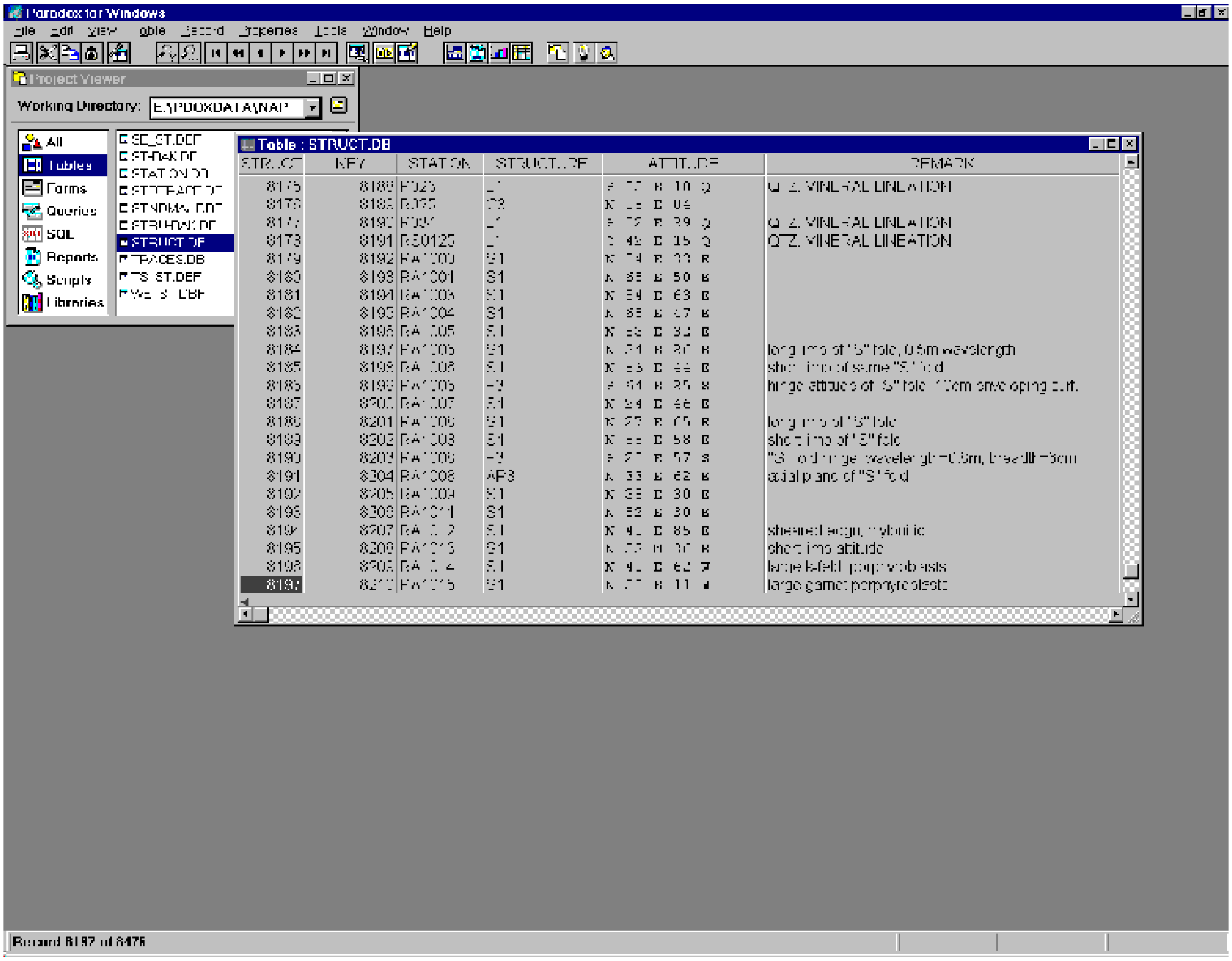

Figure 16: Structure database example from the northern Alabama Piedmont data.

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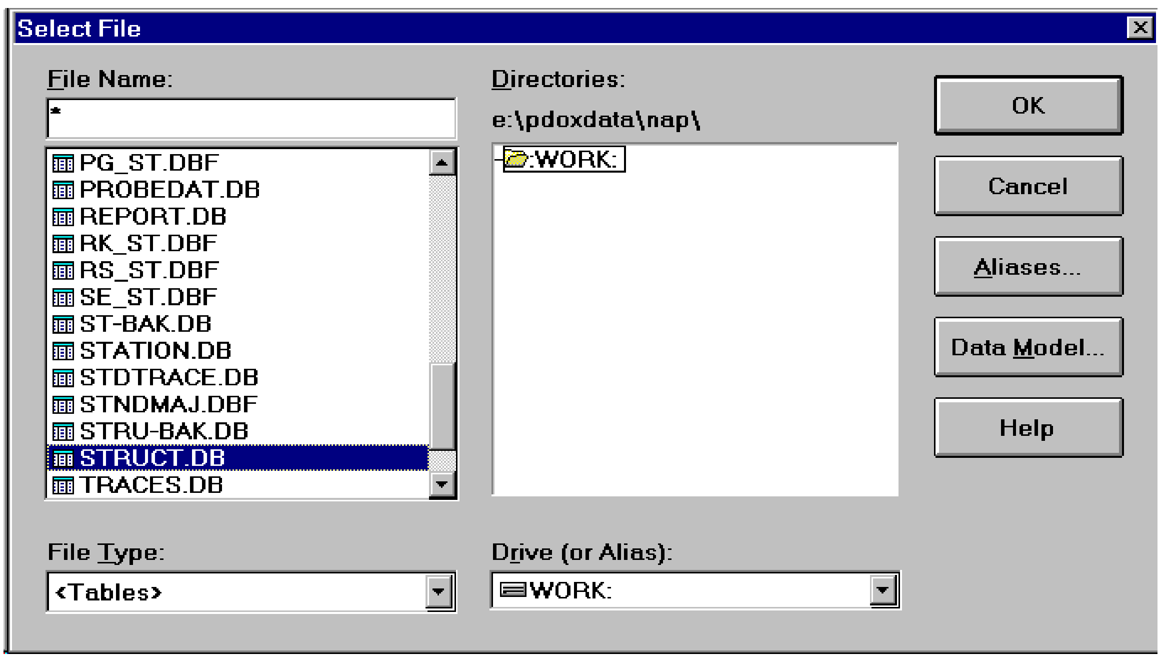

Figure 17: Dialog activated by Paradox when creating a new query.

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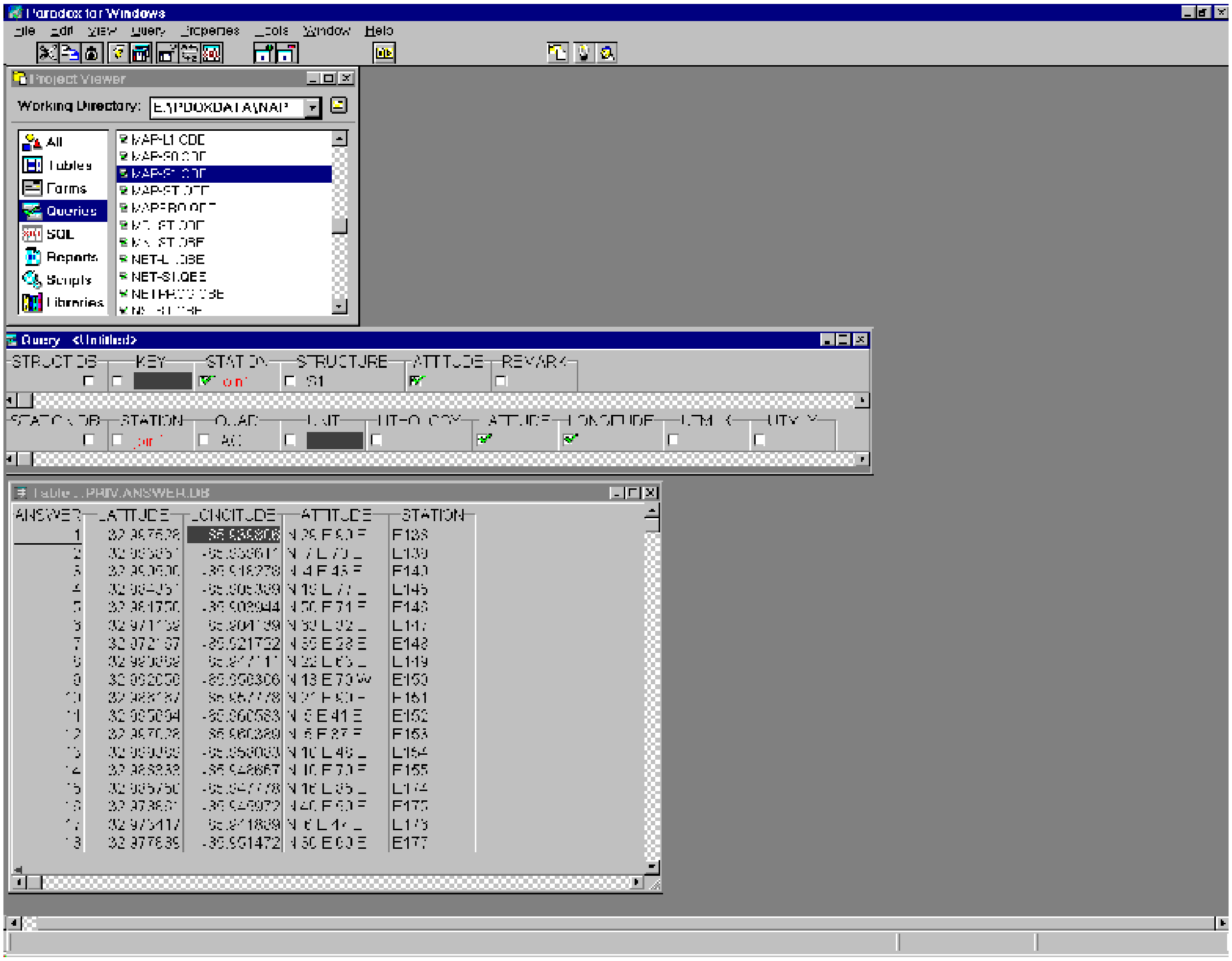

Figure 18: Appearance of Paradox structure query with answer table displayed at bottom.

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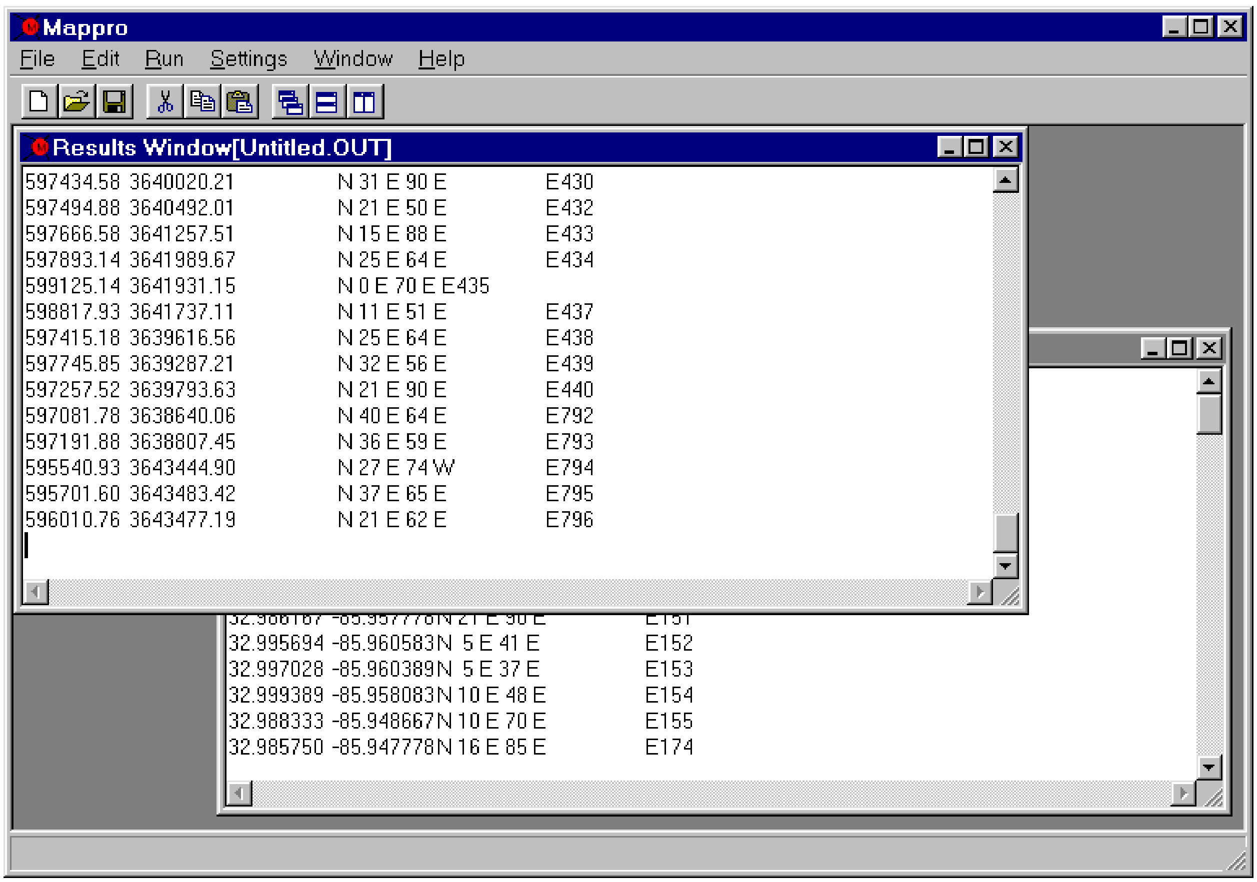

Figure 19: Appearance of MAPPRO after processing the S1 structure data.

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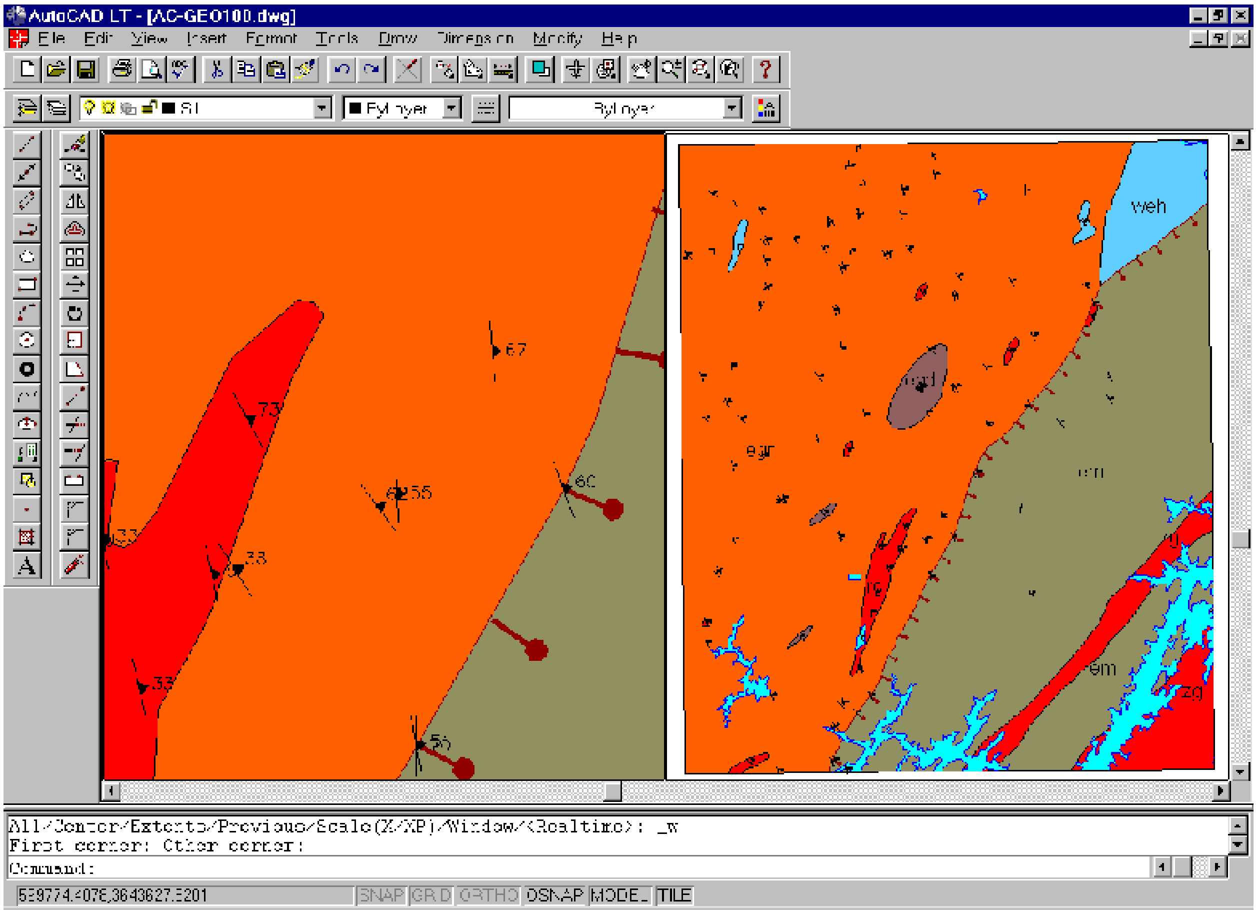

Figure 20: Quadrangle in AutoCAD Map editor displaying the posted S1 structure data.

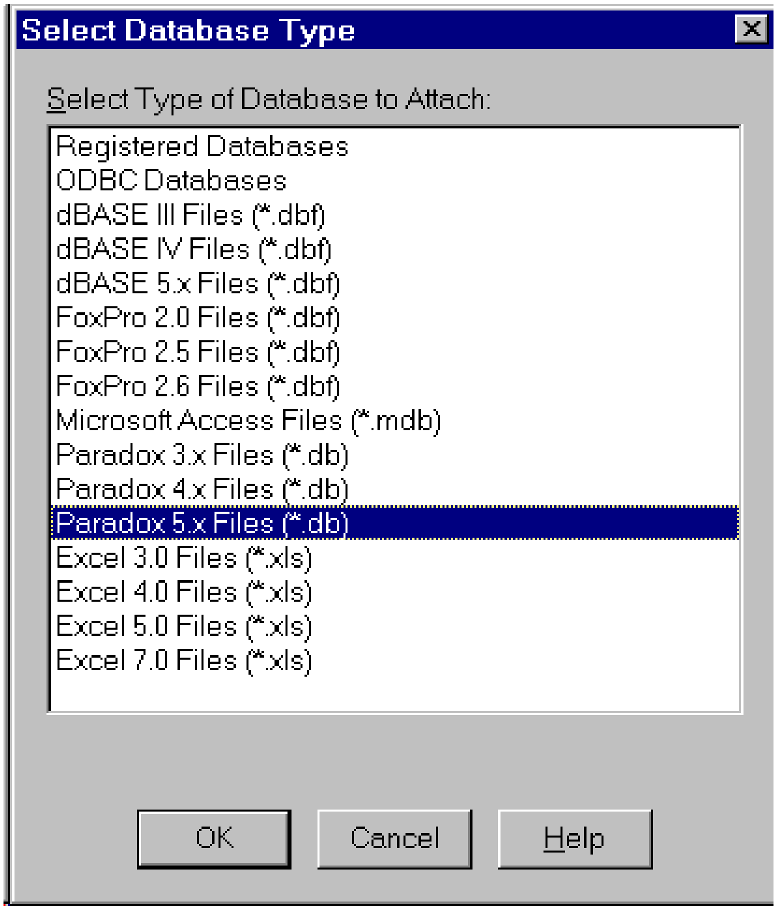

Figure 21: Dialog activated when selecting the type of attached database table.

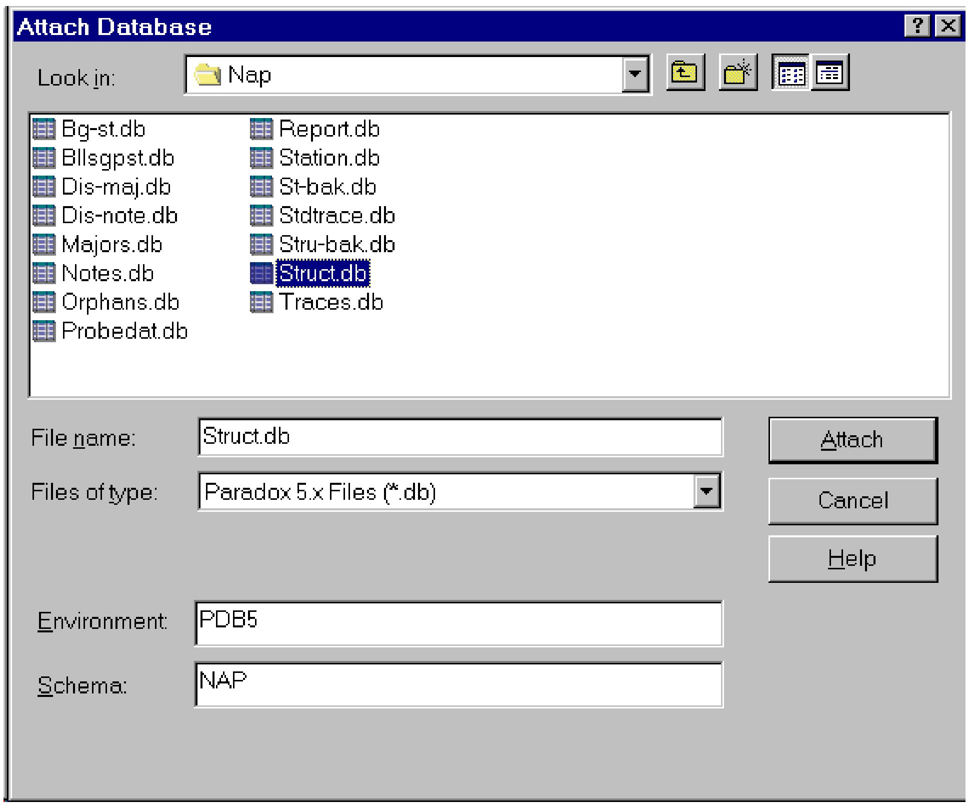

Figure 22: File dialog activated during the attach database procedure.

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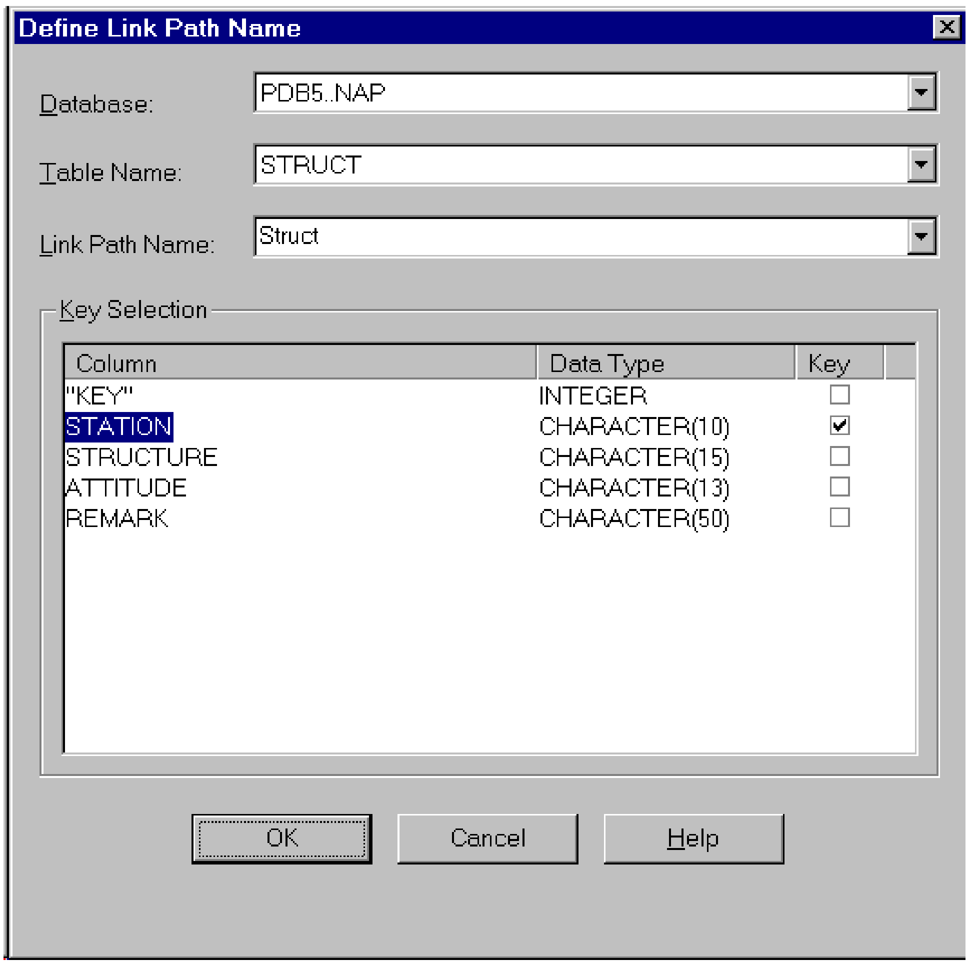

Figure 23: Dialog activated by the “Map > Database > Define Link Path Name” menu sequence.

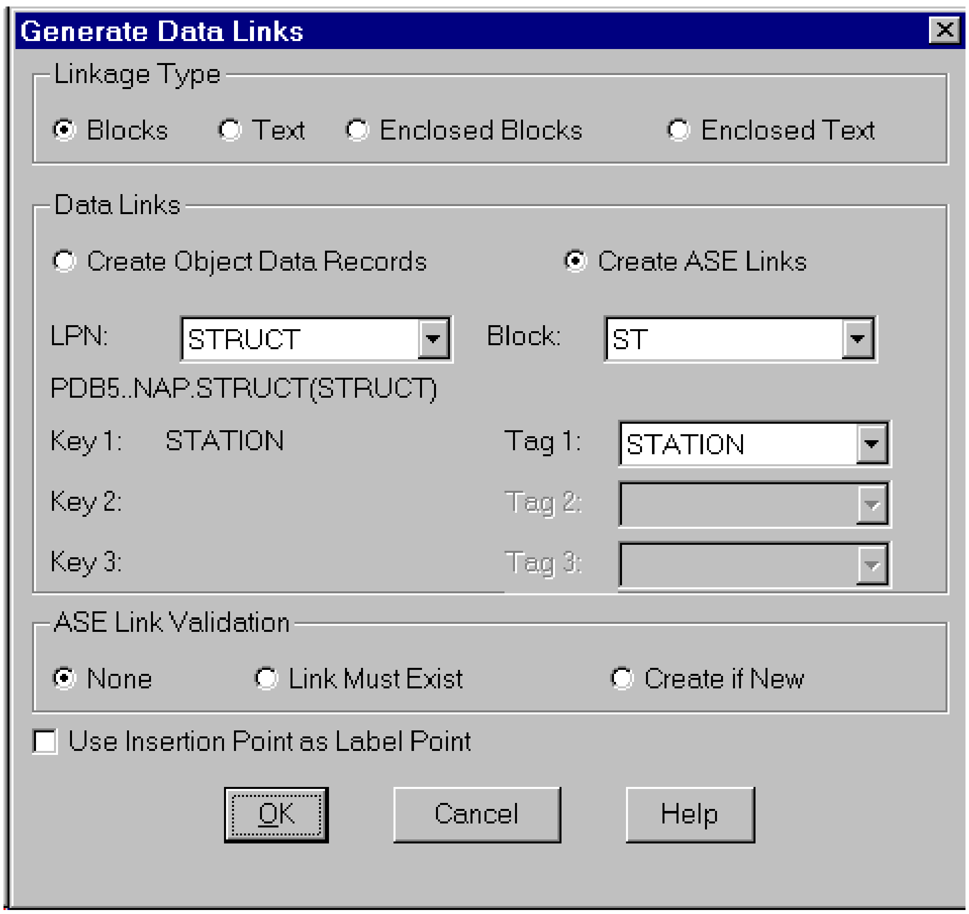

Figure 24: Dialog generated during the generation of links between the station block attributes and the structure database.

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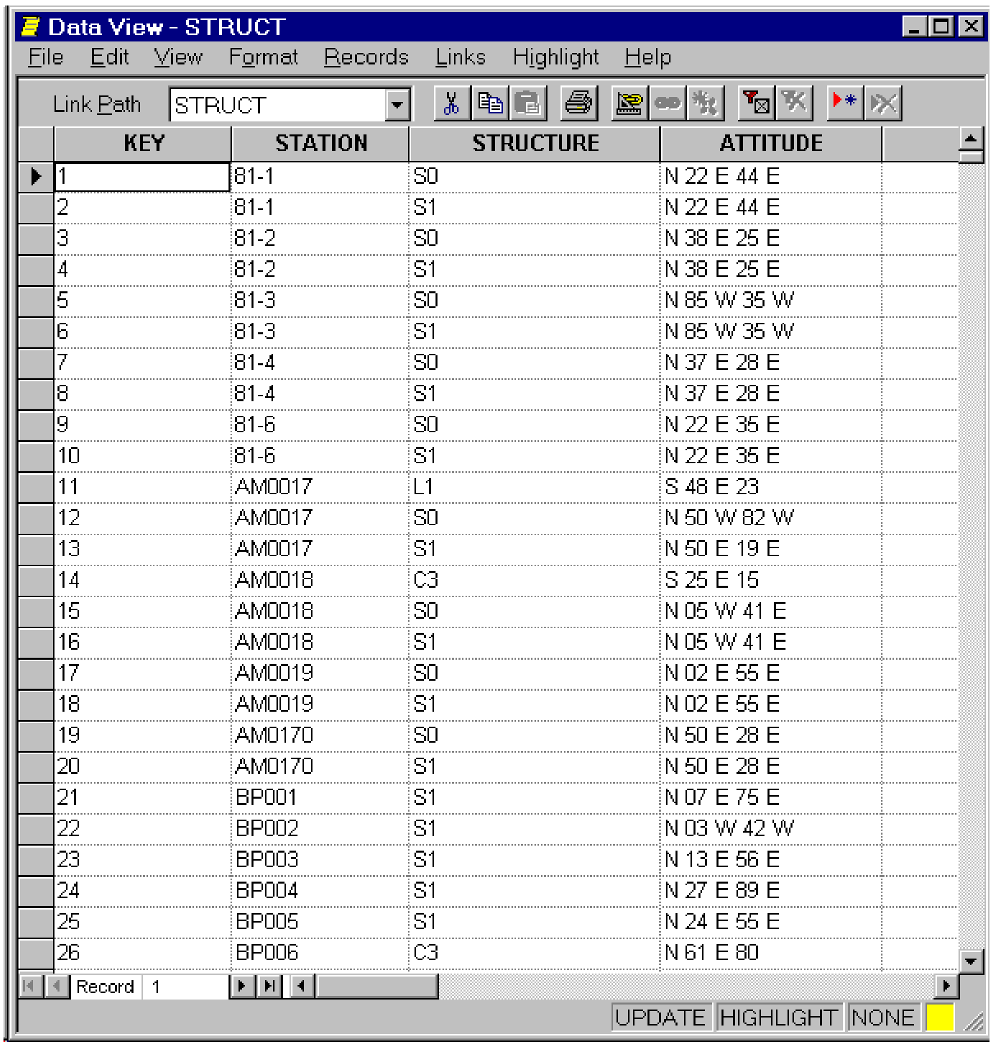

KEY	STATION	STRUCTURE	ATTITUDE
1	81-1	S0	N 22 E 44 E
2	81-1	S1	N 22 E 44 E
3	81-2	S0	N 38 E 25 E
4	81-2	S1	N 38 E 25 E
5	81-3	S0	N 85 W 35 W
6	81-3	S1	N 85 W 35 W
7	81-4	S0	N 37 E 28 E
8	81-4	S1	N 37 E 28 E
9	81-6	S0	N 22 E 35 E
10	81-6	S1	N 22 E 35 E
11	AM0017	L1	S 48 E 23
12	AM0017	S0	N 50 W 82 W
13	AM0017	S1	N 50 E 19 E
14	AM0018	C3	S 25 E 15
15	AM0018	S0	N 05 W 41 E
16	AM0018	S1	N 05 W 41 E
17	AM0019	S0	N 02 E 55 E
18	AM0019	S1	N 02 E 55 E
19	AM0170	S0	N 50 E 28 E
20	AM0170	S1	N 50 E 28 E
21	BP001	S1	N 07 E 75 E
22	BP002	S1	N 03 W 42 W
23	BP003	S1	N 13 E 56 E
24	BP004	S1	N 27 E 89 E
25	BP005	S1	N 24 E 55 E
26	BP006	C3	N 61 E 80

Figure 25: Database viewer window activated by the "browse database" menu choice.

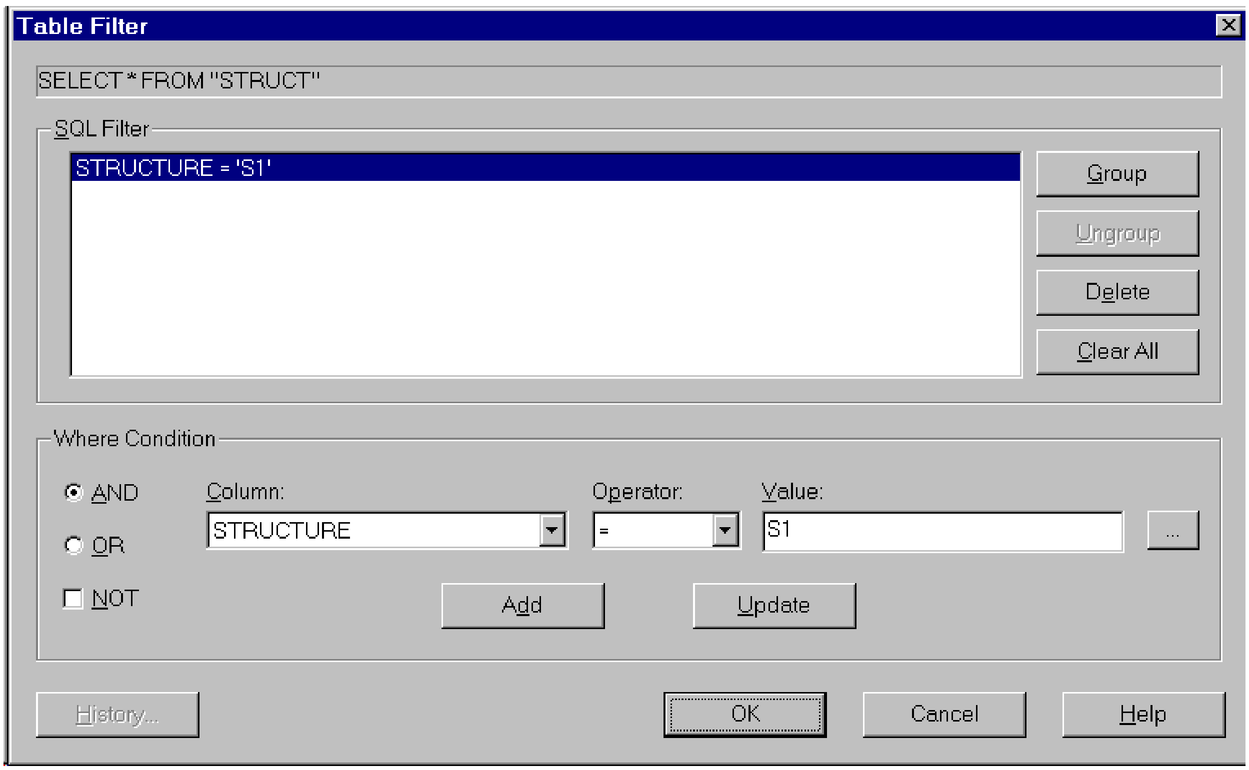

Figure 26: The SQL filter used to select only S1 data.

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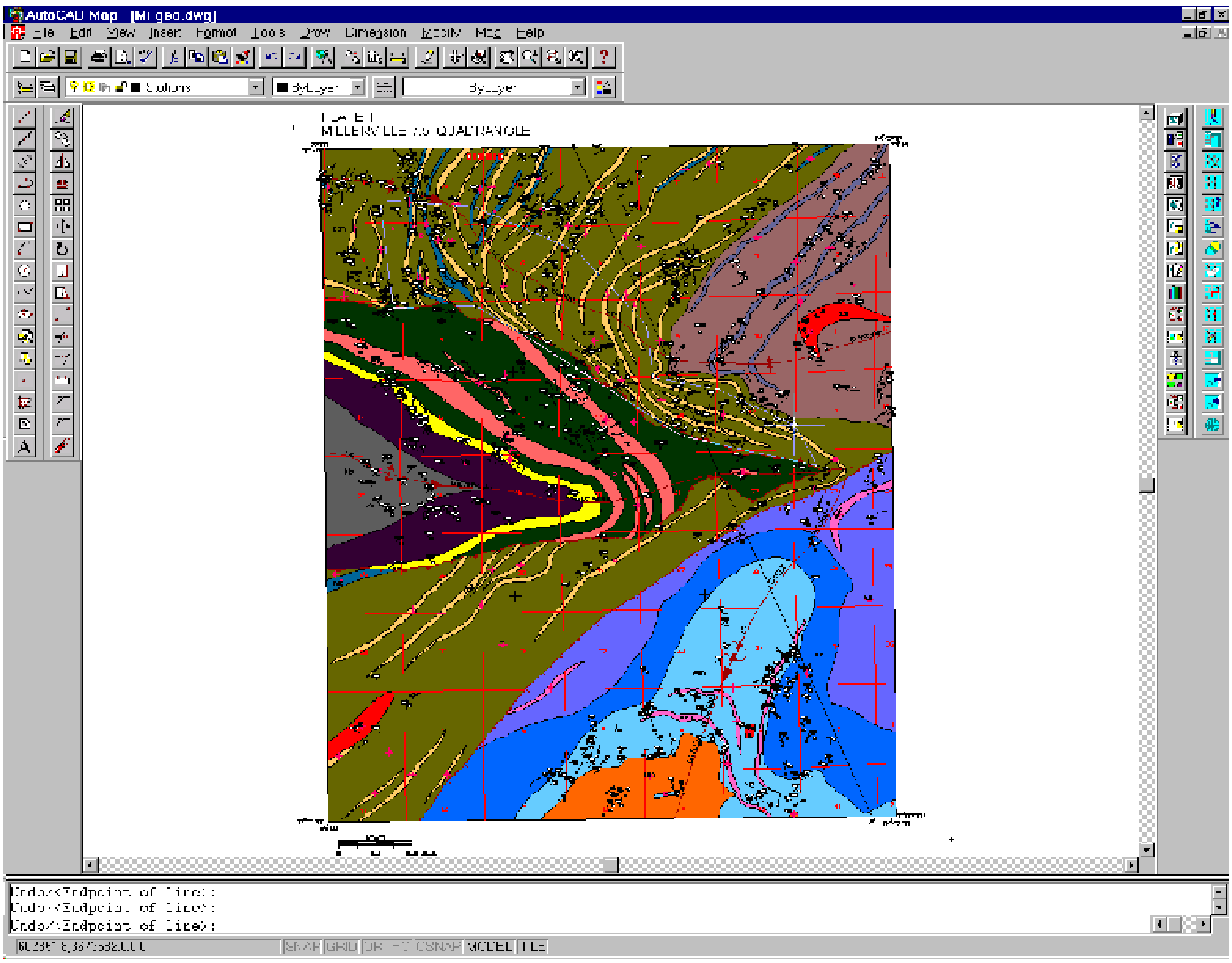

Figure 27: AutoCAD Map with Millerville quadrangle loaded, and window polygon selecting a subarea of station data.

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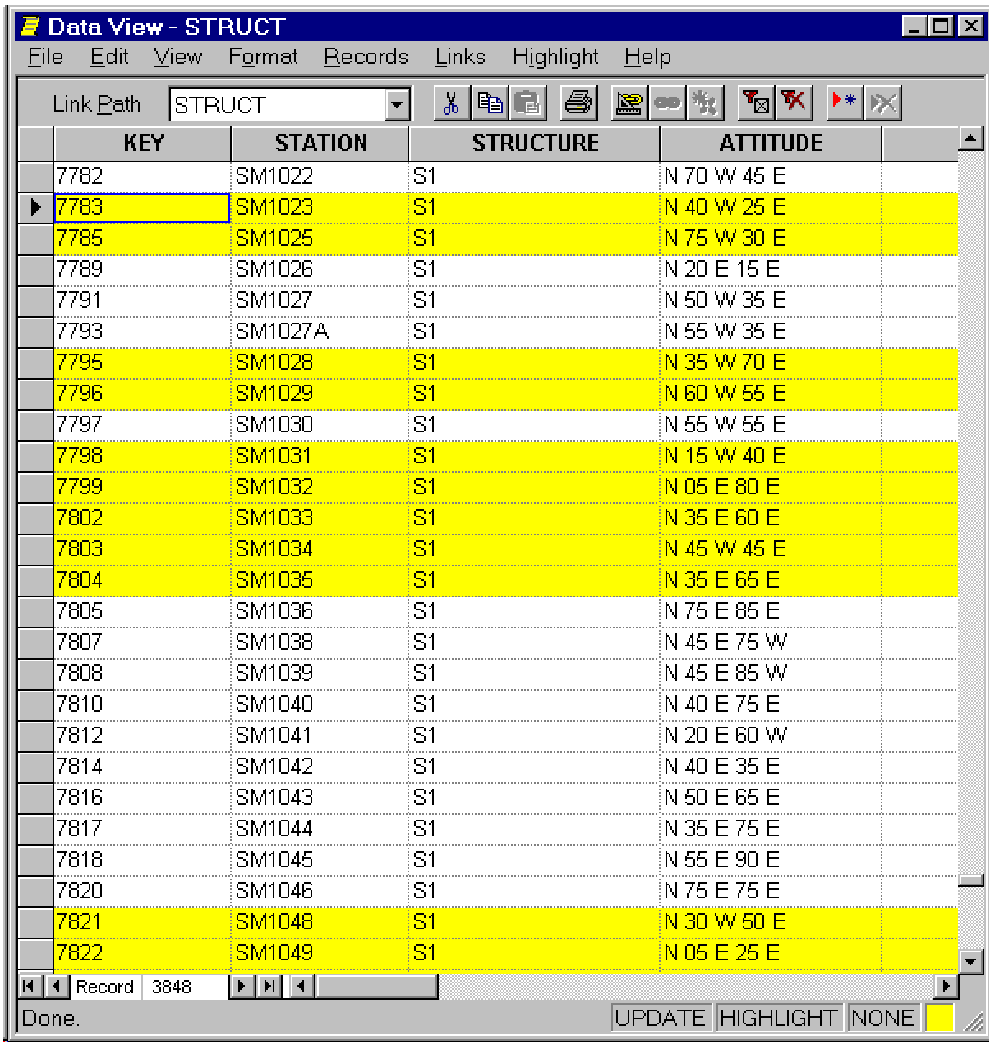

KEY	STATION	STRUCTURE	ATTITUDE
7782	SM1022	S1	N 70 W 45 E
7783	SM1023	S1	N 40 W 25 E
7785	SM1025	S1	N 75 W 30 E
7789	SM1026	S1	N 20 E 15 E
7791	SM1027	S1	N 50 W 35 E
7793	SM1027A	S1	N 55 W 35 E
7795	SM1028	S1	N 35 W 70 E
7796	SM1029	S1	N 60 W 55 E
7797	SM1030	S1	N 55 W 55 E
7798	SM1031	S1	N 15 W 40 E
7799	SM1032	S1	N 05 E 80 E
7802	SM1033	S1	N 35 E 60 E
7803	SM1034	S1	N 45 W 45 E
7804	SM1035	S1	N 35 E 65 E
7805	SM1036	S1	N 75 E 85 E
7807	SM1038	S1	N 45 E 75 W
7808	SM1039	S1	N 45 E 85 W
7810	SM1040	S1	N 40 E 75 E
7812	SM1041	S1	N 20 E 60 W
7814	SM1042	S1	N 40 E 35 E
7816	SM1043	S1	N 50 E 65 E
7817	SM1044	S1	N 35 E 75 E
7818	SM1045	S1	N 55 E 90 E
7820	SM1046	S1	N 75 E 75 E
7821	SM1048	S1	N 30 W 50 E
7822	SM1049	S1	N 05 E 25 E

Figure 28: Database viewer window after subarea data has been highlighted.

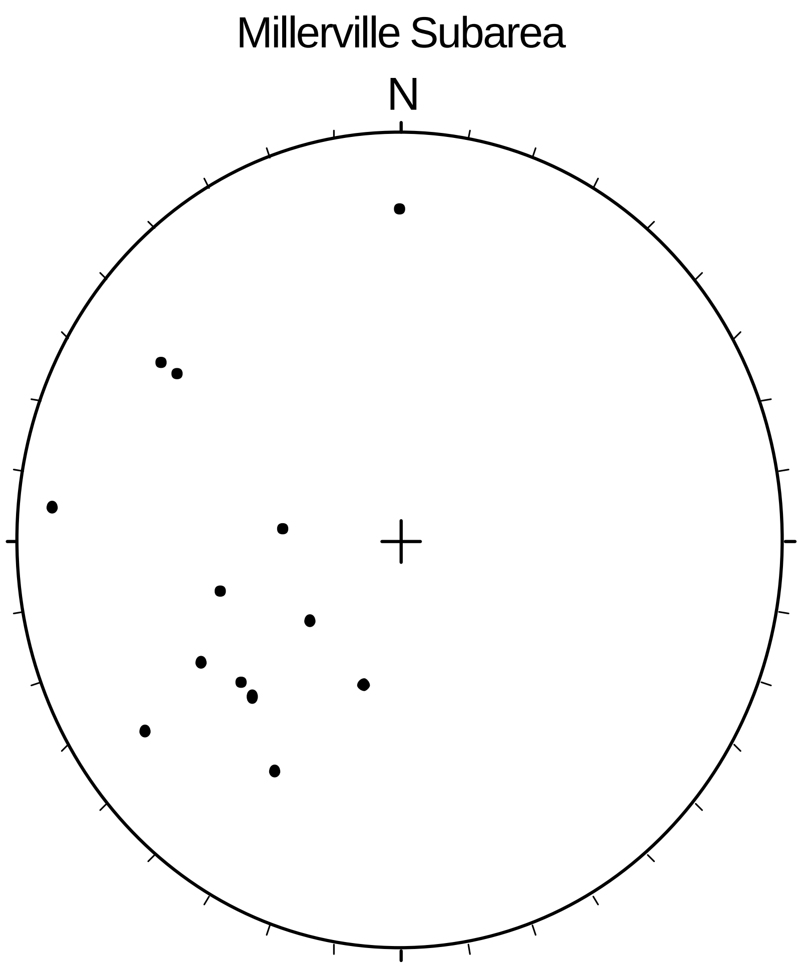

Figure 29: Example of subarea structure data plotted on a stereonet.