Geology 324 – Sedimentology and Stratigraphy
Basin Analysis – Fence Diagrams, Isopach and Structure Contour maps

The following exercises have been chosen for their relative simplicity and realism. Each is an example of a technique or method used extensively in modern stratigraphic work in the petroleum industry.

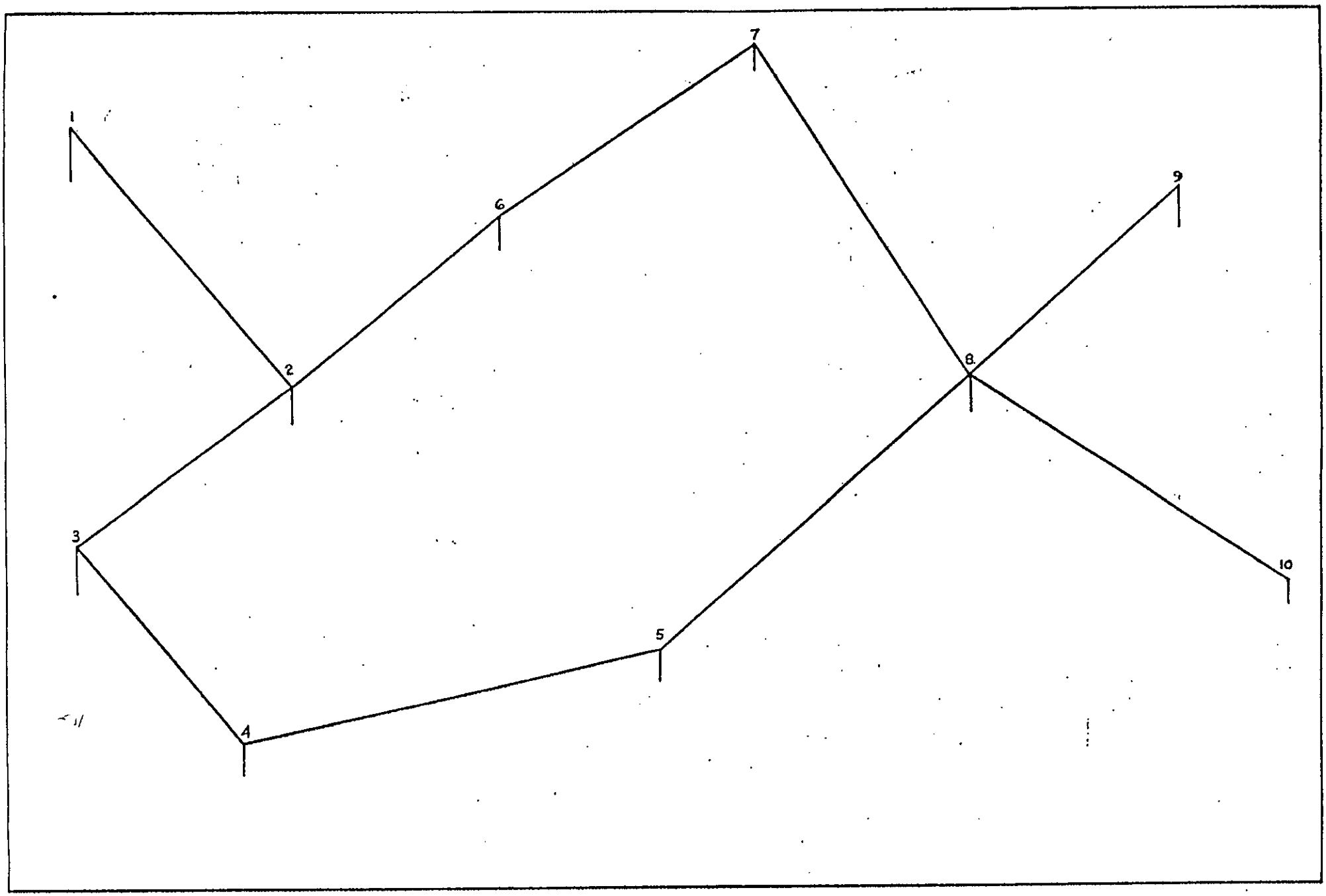
PART I: Fence Diagram of laterally variable facies. The figure on the next page is a map showing the locations of 10 wells. The table below includes the penetrated intervals of four major lithologies encountered in the wells, the depths to the top of Permian and Cambrian strata, and the total depths of the wells.

Well #	Coarse Sandstone	Fine Sandstone	Shale	Limestone	Top of Permian	Top of Cambrian	Total Depth
1	2000-3250				2000	3250	3700
2	1900-2650	1600-1900			1600	2650	3700
3	2100-3600				2100	3600	4300
4	2100-3100	1450-2100			1450	3100	3550
5	3650-3800	2020-3650	1300-2020		1300	3800	4100
6		1850-3250	1400-1850		1400	3250	3700
7		1950-2200	1100-1950		1100	2200	3180
8		3180-4200	1600-2100; 2700-3180	2100-2700	1600	4200	4900
9			1700-2550; 3450-4200	2550-3450	1700	4200	5200
10		2100-2300	1300-2100		1300	2300	3200

Procedure:

Using a scale of 1' = 2000', extend a vertical line downward from the well locations and plot the total depth of each well. On this line, scale off the intervals of the various lithologies penetrated. The upper limit of the panel represents the unconformity at the top of the Permian (isochronous surface 2). The base of the Permian is marked by an erosional surface (isochronous surface 1). Show these surfaces by wavy lines. Correlate the various lithologic units in the wells and develop panels along the lines connecting the wells on the map. The correlation lines should be drawn so as to demonstrate irregular intertonguing relationships of the various deposits (use gentle zig-zags). Work initially in pencil, then ink in the lithologic boundaries, and color, with appropriate symbols, the rock types.

PART II: Constuction of structure contour, gross isopach and net oil sand map for the Tres Lagos Formation. After graduating from Cornell College and taking a job as a geologist for a large independent petroleum producer in Oklahoma City, OK, you begin your training period for the company. Soon you hear that the next phase of your training will be observing and helping one of the company's on-site geologists. You are assigned to a field being developed in the Reforma area of Mexico. One of your first assignments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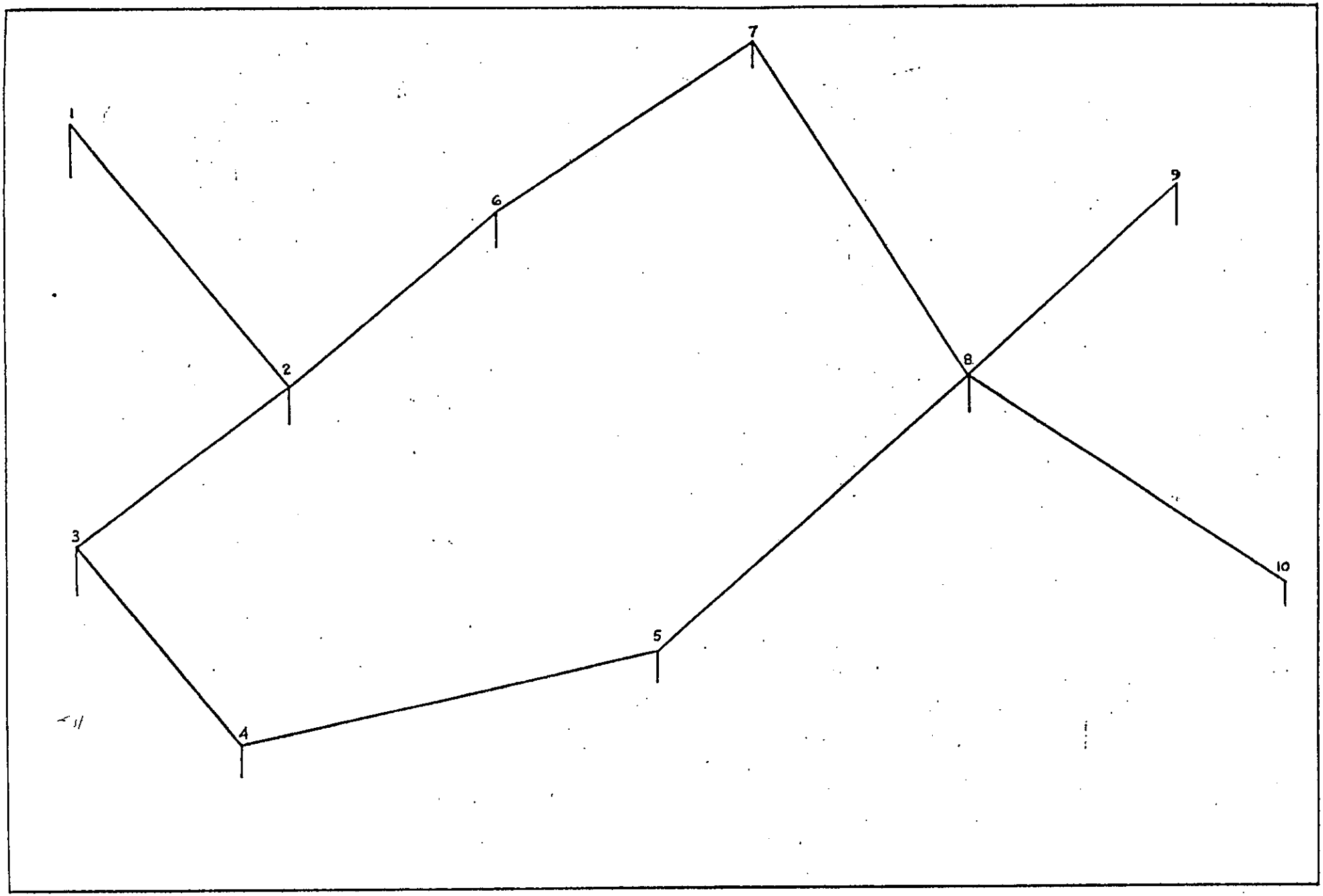
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is to create a structure contour map, gross isopach map and a net oil sand map for the oil-bearing formation being drilled. The senior geologist gives you data obtained from the electric logs of sixteen wells completed and their base map coordinates. She wants to know where you recommend drilling well #17 in order to maximize capture of petroleum. The data include: Well #, each well's location in UTM (Universal Transverse Mercator) coordinates (Easting and Northing values) depth to the top of the zone (oil-bearing unit); depth to the bottom of the zone; zone thickness; and depth of the oil/water contact.

You realize that your only hope to keep your job is to analyze the data using the latest version of Rockworks.

Procedure:

- Follow the instructions for generating structure contour maps and isopach maps given in Appendix I.
- I will leave it to you to figure out which are "wet" (producing) wells, but hint that it involves using the depth of the oil/water contact in combination with the maps you have produced, and reading part C, below.

A. Gross isopach map – This relates the thickness of a particular rock unit by plotting the thickness measured in the wells on a base map. All of the data you need have been provided.

B. Structure contour map – A structure contour map shows the contour, or topography, of the surface of an underground formation at depths determined by correlation "picks" on the well's electric logs or drilling sample cuttings of the wells drilled into the formation. Construct a structure contour map of the top of the formation, and use a contour interval of 100'.

C. Net Oil Sand Map – The net oil sand is that portion of the gross sand that is saturated with hydrocarbons and is above the oil/water contact. For this oil field the oil/water contact is at –5700 feet (below sea level). Define whether each well is an oil-producing well (greater than 5 feet of "pay" – oil in the sandstone) or a dry hole. In reality, a dry hole (well) means a non-producing well with all of its sand below the oil/water contact. A dry hole may be saturated with saltwater, encounter a non-porous or non-permeable zone, or may not be drilled deep enough.

For this portion of the lab you should turn in a gross isopach map, structure contour map with the producing wells labeled, a net oil sand map, and answer the following questions:

1. The hydrocarbon trap in this oil field is the result of which of the following: anticline, syncline, a normal fault, a nonconformity, or a permeability barrier?

2. Where would you suggest drilling Well #17.

Remember, this is your first assignment for your new company. Your performance rating, future promotion and job security depend on your work. Moreover, well #17 will cost approximately $3 million to drill; don't miss!

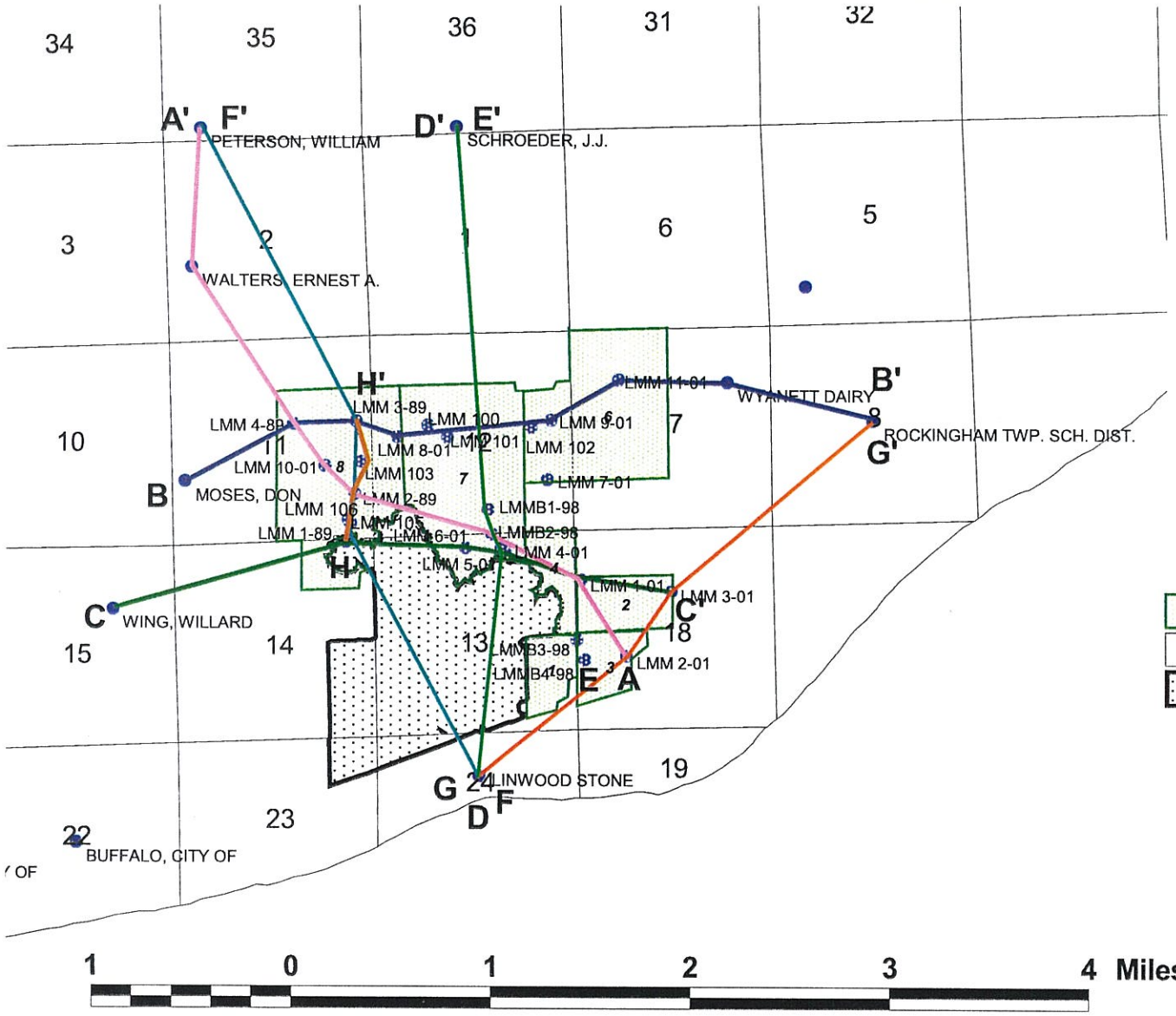
PART III: Putting it all together: An application of fence diagrams and isopach maps to the future mining activities at Linwood Mine, Davenport Iowa. Linwood Mining and Minerals Co. extracts limestone from the Davenport and Otis Members of the Wapsipinicon Formation. Mining activities occur in a "room and pillar" configuration, in which the material is removed producing "rooms" that have thick "pillars" of undisturbed bedrock that support the ceiling. Limestones of the Cedar Valley Formation immediately overlie the Davenport. These limestones are, in turn, overlain by poorly-indurated sandstones of Pennsylvanian age. Mining operations can be conducted safely only where the resulting rooms and pillars are overlain by > 10' of the Cedar Valley Formation. The limestone has the structural integrity to serve as a "roof" for the mine. The poorly indurated sandstones do not possess this integrity and hence cannot support the weight of overlying bedrock and Quaternary sediments once the underlying limestones are removed.

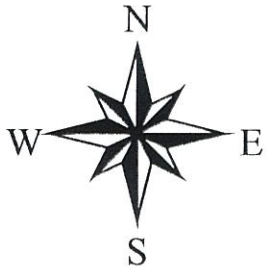
In 1998, the mining company hired Paul Garvin to assess the disposition of the bedrock geology within the mine property boundary (indicated by the shaded and stippled patterns on the attached map). Specifically, mine managers were interested whether it was feasible to extend room and pillar operations into un-mined land owned by the company (i.e., from the area with the stippled pattern into the area indicated in green on the attached map). Beginning in the summer of 1998 and continuing until his retirement in 2005, Paul worked with several geology majors logging cores obtained from several wells drilled on Linwood property. The wells were placed along six traverses across the property – the traverses are labeled A-A', B-B', etc., on the attached map. The wells are marked by dots on the map, and are labeled beginning with "LMM" followed by a series of numbers. I have loaded the cumulative data into the Rockworks program for analysis.

Procedure:

Using the Rockworks Program, generate a series of fence diagrams that illustrate the relationships of the Otis, Kenwood, Davenport, Cedar Valley and Pennsylvanian units. You should also produce an isopach map for the units that are mined, as well as one for the important "ceiling former", the Cedar Valley limestones. Compare your results to the map on the next page and prepare a written report to the management of the company. In this report you will identify whether mining can continue on the property owned by the company. If so, in which direction, within the mine land holdings, mining operations should continue, and why (i.e., include the relevant fence diagram(s) and isopach maps and an explanation of them). Should the mine exercise their lease option on the additional land (indicated in green)? Remember, the safety of human beings and the profitability of the company are in your hands!

Linwood Mine Exploration Project 2001-02
Cross Section Locations





- Unmined Area Blocks
- Land Survey Sections
- Linwood Mine Map
- Drill Core Locations

1 0 1 2 3 4 Miles

BASIN ANALYSIS LAB, APPENDIX I – A primer on Rockworks15.

Go to Assignments-BGreenstein-Sed_Strat. Copy the folders titled "Linwood Mine" and "System" and the files titled Tres Lagos Fmt.atd and Linwood.atd to your H drive.

1. Open Rockware Folder from the "All Programs" menu. Then open Rockworks15 (blue icon). Type your User ID into the "Network User ID" window. Check the box to skip menu the next time the program is executed; click continue. Close the welcome screen and cancel the update offer.
2. For the Tres Lagos Project:
    a. Click the "Utilities" tab on the very left side of the window.
    b. Open the Tres Lagos Fmt.atd file using the file menu – click "yes" when asked to match the project path.
    c. For the Structure Contour map - Click "scan data sheet" (it's in a little white box in the upper central portion of the window) and then make sure that x-column is set to Easting, y-column is set to Northing and z-column is set to Top of Zone (in the upper left portion of the window). Click "Process" (bottom left corner of window).
    d. Choose "Grid-based map" from the Map menu – the left column in the window should still read Easting, Northing and Top of Zone. In the middle column, make sure that datasheet is checked for data source, create new grid is checked (name it whatever) and that the Create 2-Dimensional Grid Diagram is checked and expanded. Check symbols, Labels, Contour Lines and Border. Uncheck Create 3-Dimensional grid diagram.
    e. Now go back and do the following
        i. Expand the labels category and click labeling options. Check "north" and choose Well # as the data column. Select black text on white background. Click OK.
        ii. Expand Contour Lines, click contour options and check "regular" and "confirm intervals". Click OK.
        iii. Expand Colored Intervals and within it check Plot color legend, then expand Plot color legend. Set x-offset to 2, width to 10. Under the grey square to the right, set cell width to 10 and the right and center margins to 1. Click OK.
    f. Click "Process" – the contour interval window should list a contour interval of 25, a labeling interval of 100 and a color interval of 25. If not, change them. Click OK. Rockworks should produce a beautiful structure contour map. Note to get out of the window, click the red "X" in the bottom left corner.
    g. For an isopach map, follow the procedure beginning with 3c, but set the z-column to Zone thickness prior to processing the scan of the data sheet.

When the contour interval window comes up, the Contour interval should be 10, the labeling interval 50 and the color interval 10.

3. For the Linwood Mine Project – you are going to create multiple fence diagrams using Rockworks to explore the structure of the beds within which the Linwood Mine is developed.
    a. After opening Rockworks, click on the Borehole Manager tab on the very left side of the window. Then go to the project menu and choose open – the select the Linwood Mine folder that you copied onto your H drive – open the folder. There should be 19 Linwood cores open in the borehole data manager. Make sure the box next to each is checked and then click "scan enabled boreholes" (again, in the little white box in the upper central portion of the window).
    b. Go to the Stratigraphy menu and select Fence-straight line correlations
    c. Choose the Fence Selection tab at the top of the screen. A map should come up with all of the Linwood boreholes indicated. You may now generate multiple fence diagrams by clicking the boreholes you wish to correlate. You can create fence diagrams using any sequence of boreholes, which should allow you to get a 3D picture of the basin in which the mine is developed. Make sure you click on the hole you want to start and end with. Tab back and forth between the stratigraphy fence and fence selection tabs to select other wells. Click the Clear button ("x") to remove previous selections on the map. You will also find the zoom tool and the fact that you can rotate your fence diagrams very useful.
4. For the Linwood isopach map. Click back to the Utilities tab and open the Linwood.atd file. Make sure UTM X and UTM Y are selected for Easting and Northing values, and the Z value can be any TH (thickness) column you wish (DAV=Davenport; CV= Cedar Valley; PP = Pennsylvanian sandstone, etc.) Follow the above instructions for making an isopach map (don't forget to scan your data sheet each time you chance the z-axis), note that in this case, you can check the 3D map option as well as 2D.

NOTE – Any of the maps/fence diagrams may be exported into file formats suitable for assembling into your typed report.