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Automatic Creation of Chronostratigraphic Columns for a Large Number of Wells

Alex Falkovskiy*, Valentina Baranova, Yelena Falkovskaya, Azer Mustaqeem, Aziz Mustaqeem and Raza Siddiqui
RM Seismic Software*, Petro-Explorers Inc.

Summary

With the increased pace of hydrocarbon exploration, the need to interpret big data faster and accurately, automation and optimization is required. We propose a method for automatic creation of chronostratigraphic columns for all wells in a zone of interest using marker-depth tables and comparison age chart. Comparison age chart for reference wells is a spreadsheet created by an expert geologist which maps age/formation codes to indexed codes of tops for each zone. Comparison age charts for all wells is then generated automatically using reference wells with chronostratigraphic columns.

Theory / Method

Necessity to reinterpret big volumes of data for old oil fields with hundreds and thousands of wells has become a distinct trend over recent years. It can be implemented in several steps. At the beginning, well data need to be digitized and volume of shale (VSH) logs are generated. Next, to each reference well picked by an expert geologist and representing each zone of the region, the chronological column has been added on the basis of Comparison Age Chart. Comparison Age Chart shows the correspondence between tops and absolute age of the formation for any given zone. Figures 1 and 2 and show examples of Comparison Age Charts for two areas: Teapot Dome (Wyoming) and Blackfoot (Alberta) datasets.

AGE_NAME	EARLY_AGE	LATE_AGE	UPPER_TOP	LOWER_TOP	COLOR	ZONE
UPPER_CRETACEOUS	79	100.5	SSXS_0790	MWRY_0980	#A6D84A	TPD1
LOWER_CRETACEOUS	100.5	145	MWRY_0980	MRSN_1450	#8CCD57	TPD1
JURASSIC	145	169	MRSN_1450	GPSP_1690	#34B2C9	TPD1
TRIASSIC	169	237	GPSP_1690	RDPK_2370	#812B92	TPD1
PERMIAN	237	294	RDPK_2370	C1Sand_2940	#F04028	TPD1
PENNSYLVANIAN	294	310	C1Sand_2940	EDolo_3100	#99C2B5	TPD1
MISSISSIPPIAN	310	333.5	EDolo_3100	MDSN_3335	#678F66	TPD1
PRECAMBRIAN	333.5	541	MDSN_3335	PC_5410	#F74370	TPD1

Figure 1. Example of Comparison Age (csv file) used as input for GeoAge for Teapot Dome dataset.

AGE_NAME	EARLY_AGE	LATE_AGE	UPPER_TOP	LOWER_TOP	COLOR	ZONE
UPPER_CRETACEOUS	66.4	97.5	DINOSAUR_PARK_0664	BASE_FISH_SCALES_0975	#A6D84A	BF1
LOWER_CRETACEOUS	97.5	139	BASE_FISH_SCALES_0975	BASE_LOWER_GLAUC_CH_1390	#8CCD57	BF1
JURASSIC	139	140	BASE_LOWER_GLAUC_CH_1390	DETRITAL_1400	#34B2C9	BF1
CARBONIFEROUS	360	360	MISSISSIPPIAN_3600	MISSISSIPPIAN_3600	#67A599	BF1

Figure 2. Example of Comparison Age (csv file) used as input for GeoAge to Blackfoot dataset.

As an input, GeoAge software uses name of a directory with LAS files, All Tops Excel spreadsheet with information about all tops for all wells in the area, and Comparison Age csv file to create STRAT format files with stratigraphic column data including VSH log, tops and geological age column.

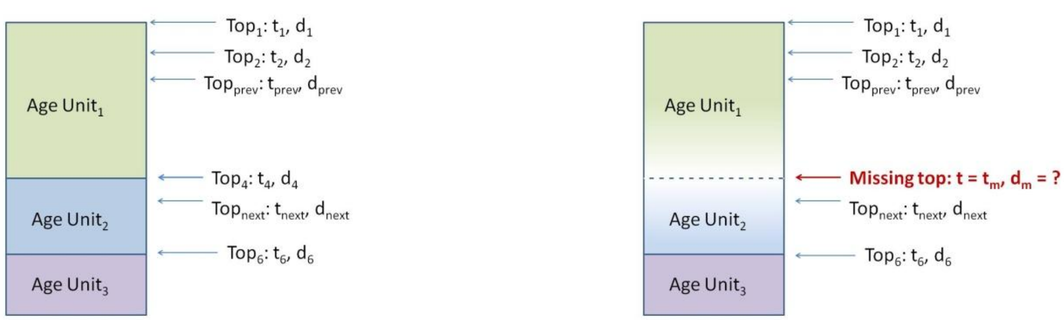
Our method using a list of tops with their depths for each well, and comparison age csv files is able to find age/formation marker depths for each well.

The most common issue of this method is a result of that Comparison Age table points to only upper and lower bound tops for each age marker. When not all tops is a well are picked, the missing top may be one of these boundary tops for an age unit. To resolve this issue, GeoAge uses linear interpolation to find missing top corresponding the boundary between two age units.

For finding the depth of the missing top, we use ratio between linear age difference and true stratigraphic depth difference

————),

where d is the depth of missing top, is depth of top in upper layer with age , is the depth of next picked top in the lower layer, and is age of this top. In this equations coefficient ———— is a rate of deposition determined from ages and relative depths of two tops.



a. Top between Age Unit 1 and 2 has been picked.

b. Missing top between Age Unit 1 and 2 interpolated.

Figure 3. Interpolation of missing tops needed to find boundaries between age units.

Workflows

There are two options to create Comparison Age Charts that are necessary to run the workflows. In the first one, Comparison Age tables are created by an expert geologist for each zone. In the second option, this tool is able to generate Comparison Age tables using geologist-created age columns only for reference wells. Then, that will be used for automatic creation of age markers.

Input data: LAS files with GR logs, table with formation tops for all wells, stratigraphic columns with age units for several reference wells.

1. Data preparation before running GeoAge tool

   - Calculate Volume of Shale (VSH) logs from GR logs, using GR2VSH software for all LAS files.
   - Expert geologist creates a Comparison Age Chart divided by zones
   - Indexing tops: Assigning age to each top as a code ending with number (eg. MWRY_3670 means age 367 Ma for top MWRY, Mowry Shale)

2. Run GeoAge tool

   Options:
   - Use Comparison Age Chart created by an expert geologist
   - As a training dataset, GeoAge tool uses several reference columns created by a geologist to generate its own Comparison Age Chart

3. Data analysis

   - Correction of depth and age errors for tops, correction of issues related to not-standard LAS format. Repeat Step1 if required
   - Otherwise output data as geochronological column displays and STRAT file

Output data: STRAT files (new format for stratigraphical data) for all wells with VSH logs, tops, and age/formation columns.

The information on stratigraphic columns is stored in developed for this purpose strat format files (similar to LAS format), and can be displayed with another tool.

Results

This section shows automatically generated stratigraphic columns with geologic age rectangles created for two oilfields Blackfoot and Teapot Dome. Figure 4 shows example for Blackfoot dataset.

There were more 1300 wells in Teapot Dome dataset with tops picked on 1082 wells. (Figure 5). Figures 6-7 show results for Teapot Dome dataset.

Note that there were no picked tops between Jurassic and Lower Cretaceous, and Triassic and Permian, and these tops were interpolated to find the boundaries between Age Units.

Figure 7 (c) shows an example when with this method any lager Age Unit can be easily split into smaller units. In this case Upper Cretaceous split into Steele, Niobrara Shale, Carlisle Shale and Frontier formations, and the main advantage is that this could be done simultaneously for all wells after a Comparison Age Chart is created.

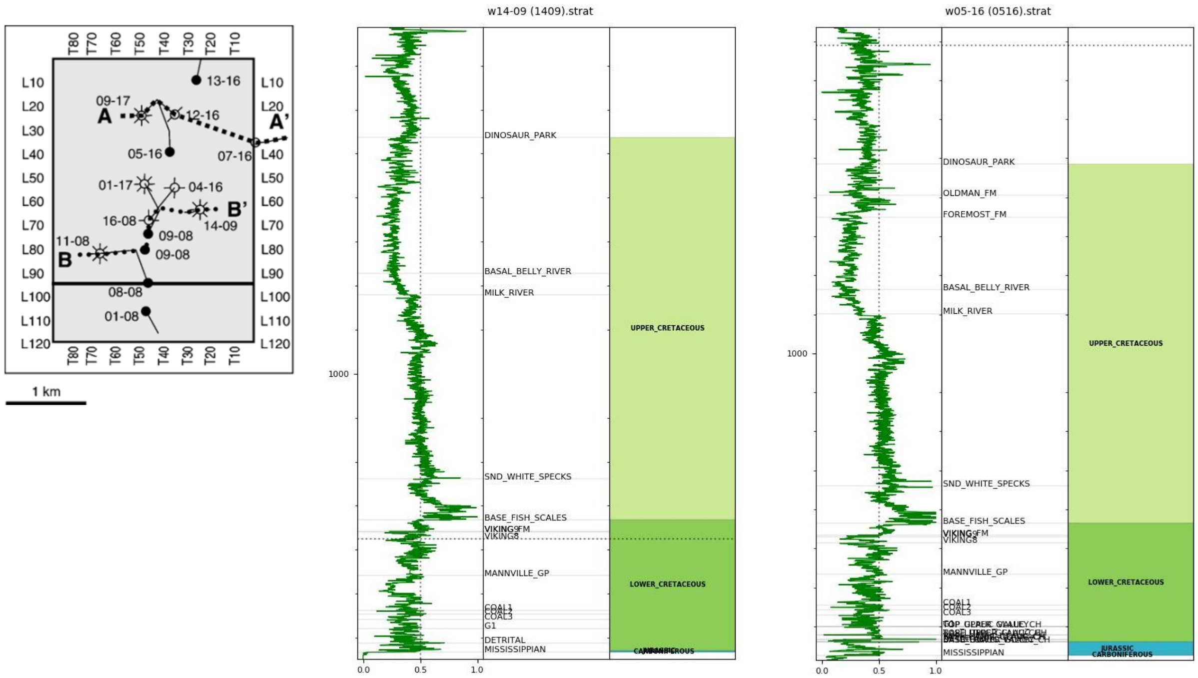


Figure 4. Blackfoot dataset: Basemap (from J. Dufour et al.) and automatically generated age columns for two wells.

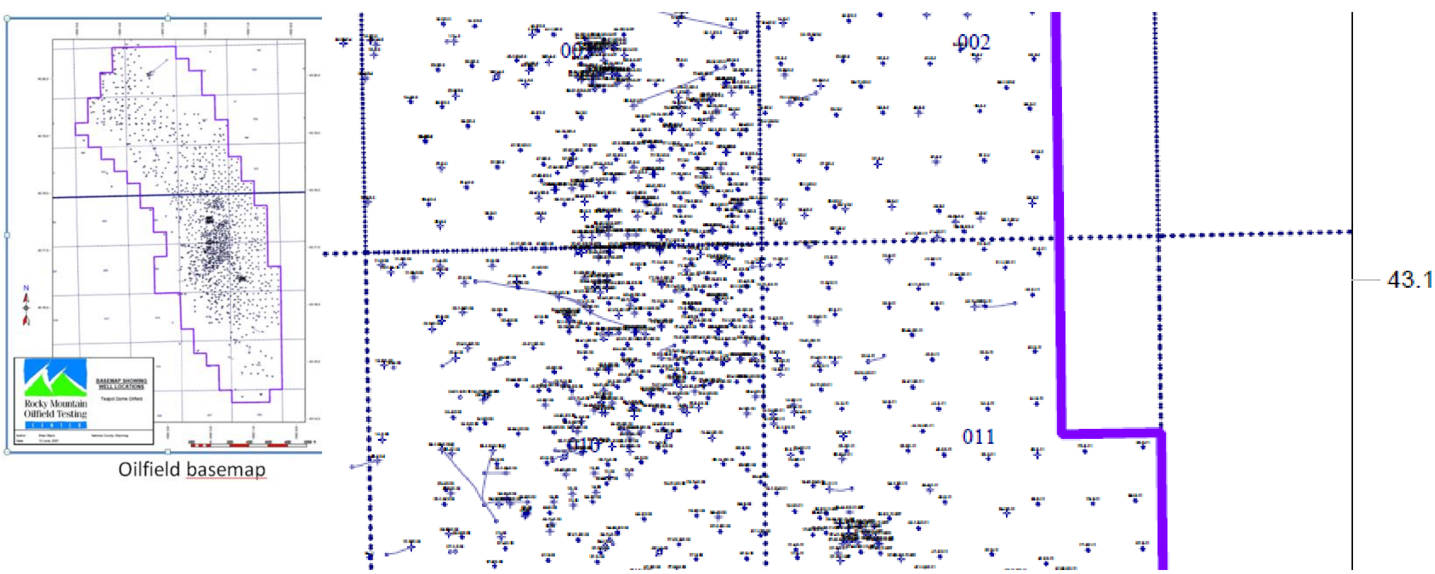
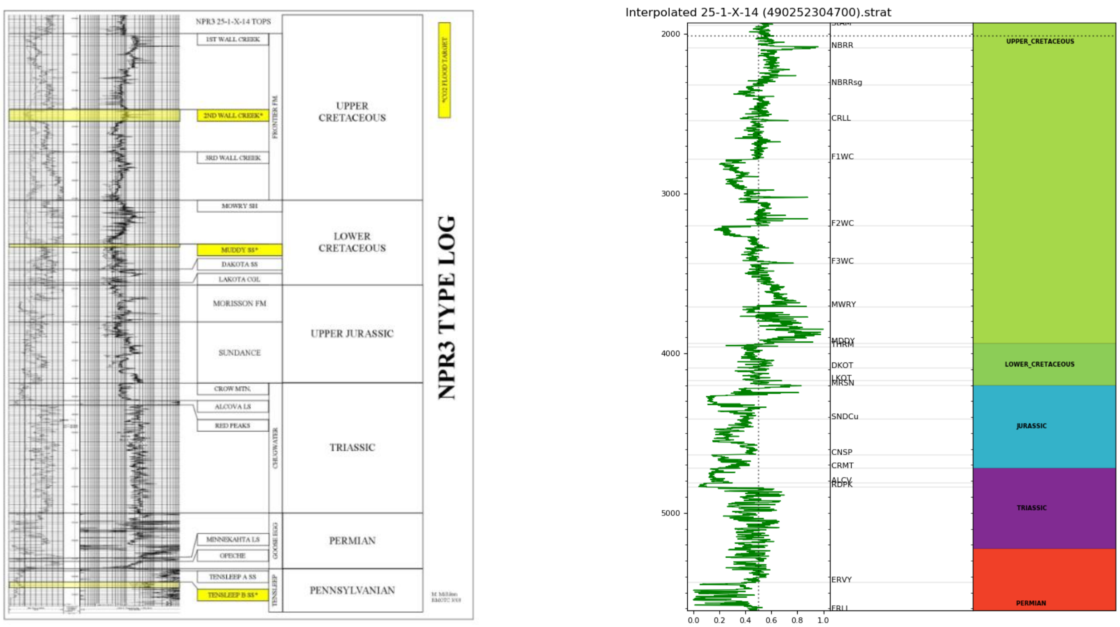


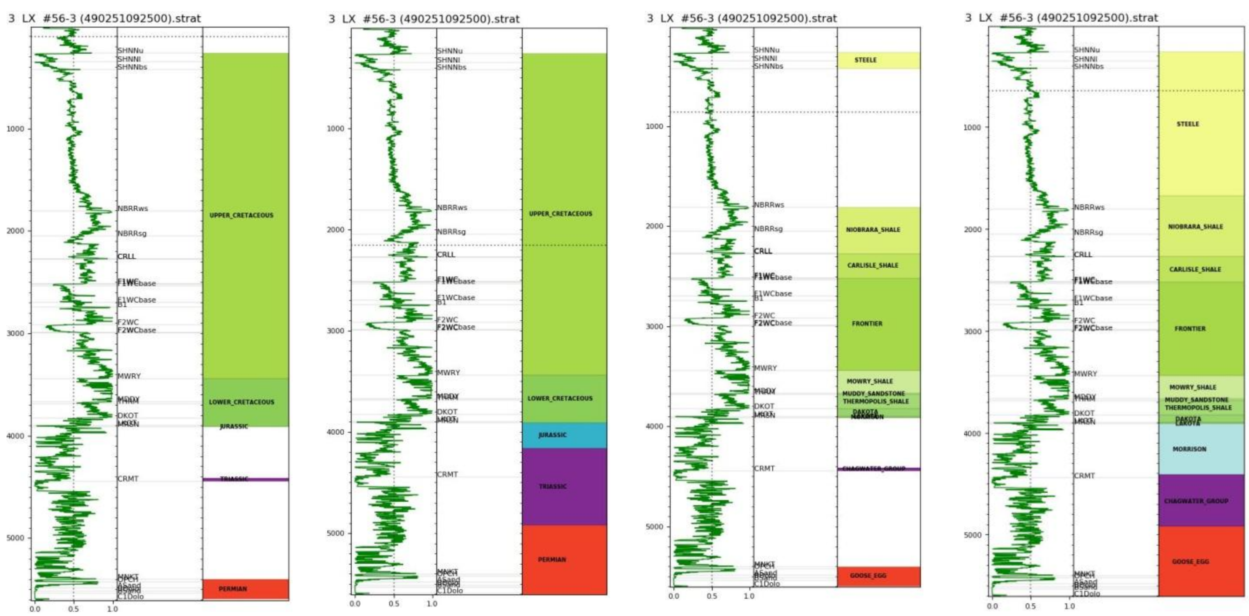
Figure 5. Teapot Dome dataset (1082 wells with formation top data): Basemap and central part zoomed.



a. Reference well

b. Created geochronological column

Figure 6. Teapot Dome dataset: Reference and recreated geochronological columns.



a. Only available tops

b. Interpolated tops

c. Lower order age units

d. Interpolated tops

Figure 7. Teapot Dome Dataset: Comparison of geological age calculation with and without interpolation of missing tops. Age units: periods (a,b) and formations (c,d).

Conclusions

The purpose of this tool is to reduce the amount of interpreter's work when it is required to add geologic time to a large number of wells, for example in a sequence stratigraphic workflow. As input data, it uses a set of LAS files (VShale logs), all tops and comparison age tables created by an interpreter to add geological age information to all strat files for a selected zone.

The result of automatic addition of geological time to stratigraphic columns is comparable with that created by interpreters. This method is trying to be conservative in interpolation, but we could exclude all gaps by interpolation over tops.

This software and method is useful when it is necessary to interpret big data from oilfields with hundreds and thousands wells. It provides good standard quality of processing for old data and possibility to try more interpretation options in a short time. In any case, this method provides essential reduction of manual interpretation work and makes it feasible to create stratigraphic sections for large fields in a short time.

Acknowledgements

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