



Apex Spectral Technology, Inc

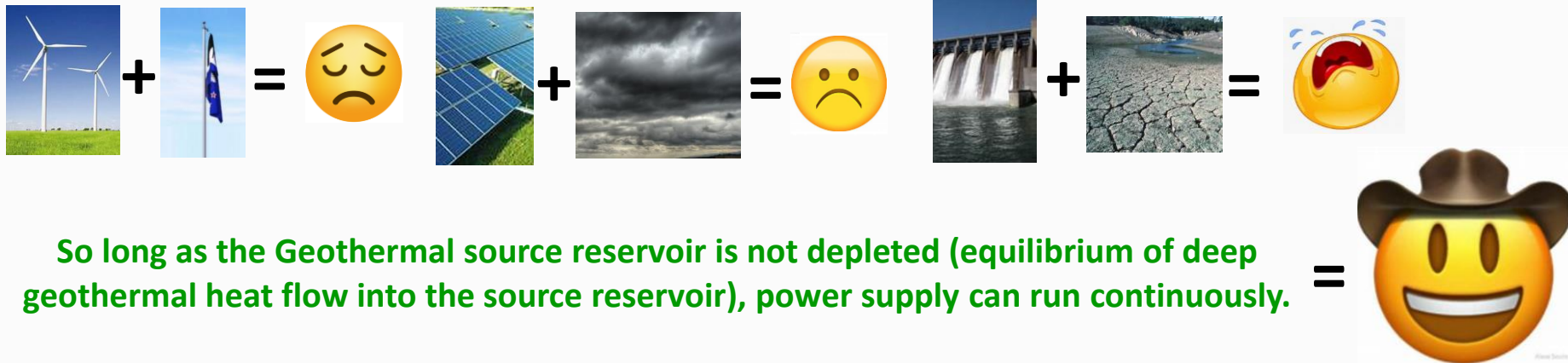
**ADF[®] Product Suite in support of
Commercial Geothermal Energy Production**

August 2021

Geothermal Energy is a renewable source of energy since the heat flowing from the earth is being replenished by natural radioactive isotope decay at the rate of about twice the worlds total power consumption in 2015 (Energy Information Administration. Pub. L. No. 110-140), and it will continue to do so for at least another billion years (Blodgett and Slack 2009 (*))!!

Geothermal energy is there ALL THE TIME.

You don't need to wait for the wind to blow or the sun to shine or the rivers to fill with water.



(*) Basics of Geothermal Energy Production and Use: Leslie Blodgett and Kara Slack, GEOTHERMAL ENERGY ASSOCIATION, Feb-2009. https://geothermalcommunities.eu/assets/elearning/7.15.geo_101.pdf

Reducing sub-surface uncertainty means controlling cost.

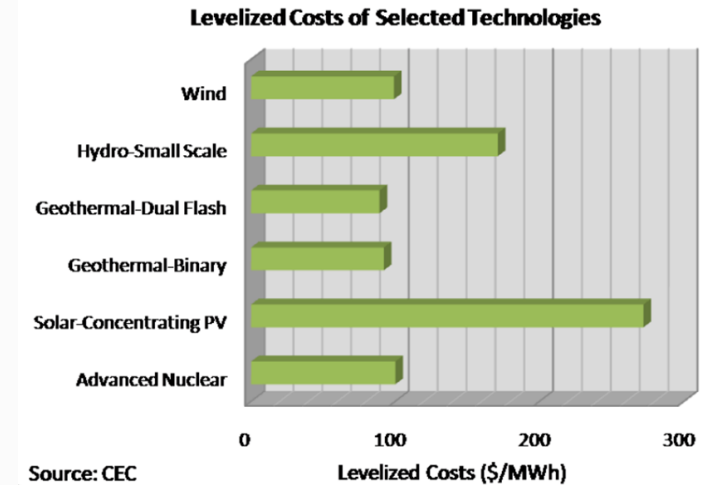


APEX

Even though overall Geothermal cost fares well against alternatives, the cost of Deep-Geothermal energy is not as universally well controlled.

Detailed historic average wind, sun and rain information enables simple unit commercial cost evaluations in those fields.

However, there are certain subsurface risks involved with deep well drilling that need to be de-risked to maintain low Geothermal energy costs.



We HAVE to be sure the regional Geothermal source is optimal for a long-term capital investment.

How can the industry reduce that risk and uncertainty in unit cost in some areas and increase the success rate of Geothermal projects?

Geothermal energy can be divided into 3 main categories.

- 1) Geothermal Heat Pumps. Simple near-surface geothermal presence driving heat exchangers for household or other use.
- 2) **Hydrothermal.** Deeper and higher temperature natural geothermal sources used to drive turbines to produce commercial quantities of electricity.
- 3) Enhanced Geothermal. Deeper and higher temperature geothermal sources that require fracking to allow sufficient water flow for hydrothermal power generation.

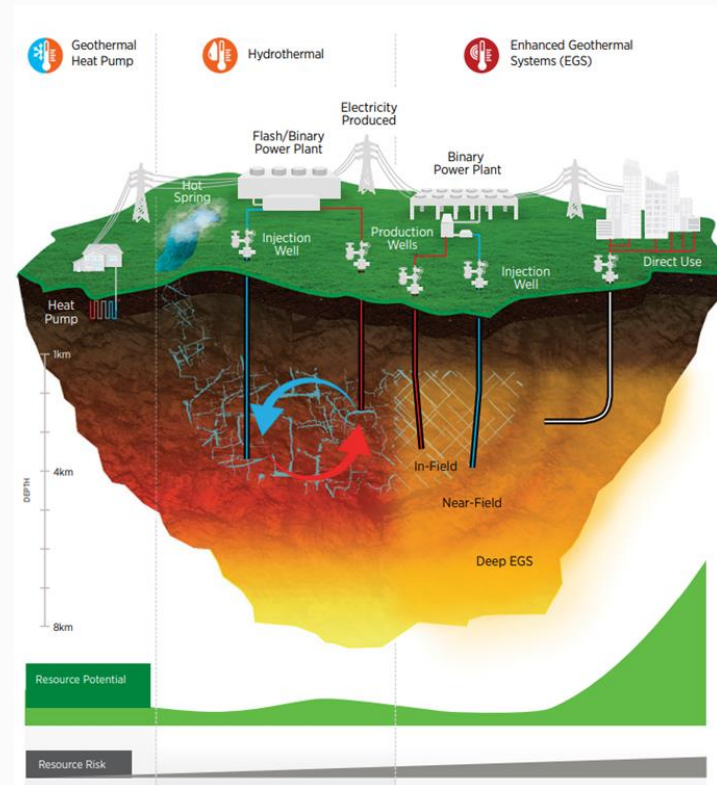
Hydrothermal power generation can be further subdivided into:

- Dry steam power plants (>150C/300f)
- Flash steam power plants (>>150C/300f)
- Binary cycle power plants,

each of which comes with varying costs to place into commercial production.



APEX



The KEY is Permeability.



APEX

Hydrothermal power generation is based on drilling deeper into the subsurface to create holes into which we can pump water (injector well) into the heat reservoir and then recover the heated water (production well).

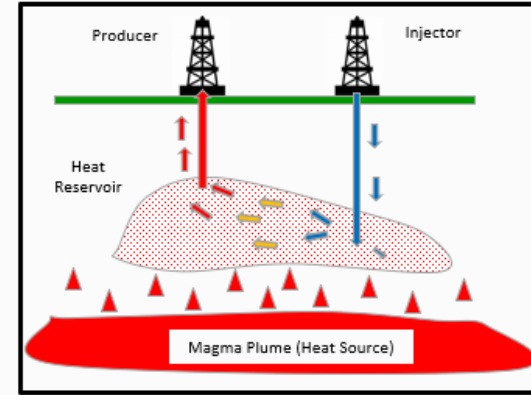
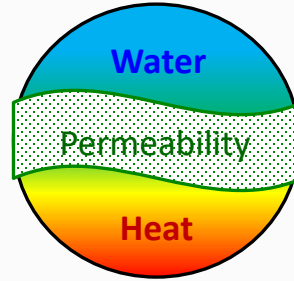
Q: What is needed?

A: Primarily, access to

Water,

Heat, and

Permeability



[Although you can pump water into a large regional permeable layer, an optimum situation is a large permeable layer which is also vertically and locally constrained such that greater control/containment over the water flow is achieved leading to a greater efficiency of the operation]

- We have water.
- We understand where the heat is (see later).
- What is key is understanding the Permeability of our targeted heat reservoir.

Why is permeability so important?



In general, the volume of water that needs to be produced per day and the mean sustainable temperature of the reservoir the water is being pumped through from injector(s) to producer(s) can be roughly estimated for the power generation plant to be commercial.

(The parameters and calculations that can go into this estimation are in fact extremely numerous and complex)

What we need to know is the EASE at which the water can be injected into and pass through the heat reservoir. The EASIER the flow and the higher the reservoir temperature, then the lower the unit cost of operation, leading to a cheaper and more sustainable alternative energy source.

Permeability is a measure of the EASE of the flow of a liquid through a porous material. The higher the permeability, the more commercial the hydrothermal prospect and, since a LOT of water flow is needed for an effective Hydrothermal plant to operate, **permeability is therefore crucial.**

Elsewhere in the USA, where higher temperatures are closer to the surface, Hydrothermal plants rely on wells some 1-3km (3,200'-9,600') in depth. Binary Hydrothermal plants can run at lower temperatures, but the most cost efficient Hydrothermal (Flash and Dry steam plants) require temperatures of 150-200C (300-400f) or greater.

When we analyze subsurface temperature maps of Texas, that means we are restricted to just certain areas and have to drill to 4.5km+ (15,000').

At this depth:

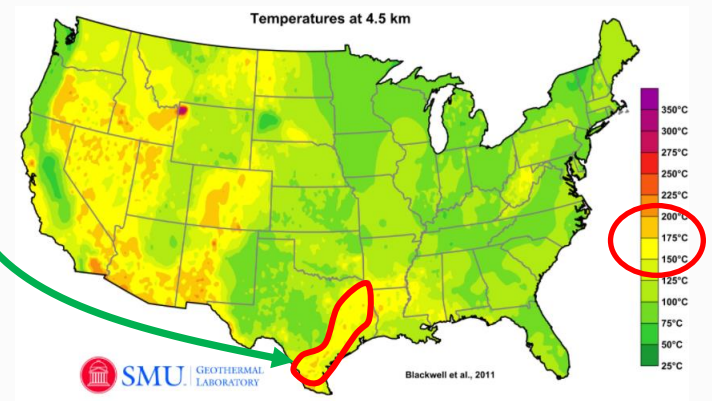
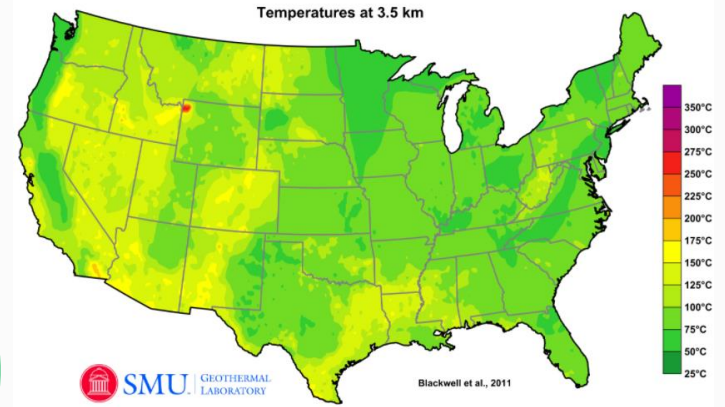
- a) The earth is more compacted/consolidated and liquid flow through rock is restricted.
- b) The wells become more expensive to drill.

Since wide (or multiple) boreholes are required for the kind of flow rates required for commerciality, it is KEY, that we understand the potential EASE of flow through the targeted trapped subsurface features in order to reduce the risk of the commercial endeavor.

<https://www.smu.edu/Dedman/Academics/Departments/Earth-Sciences/Research/GeothermalLab/DataMaps/TemperatureMaps>



APEX

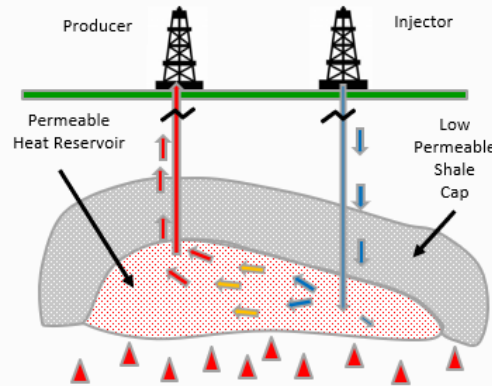
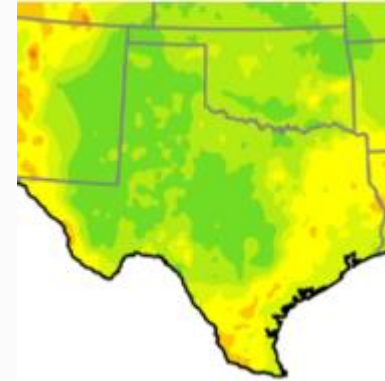


ENTER Apex and ADF®.

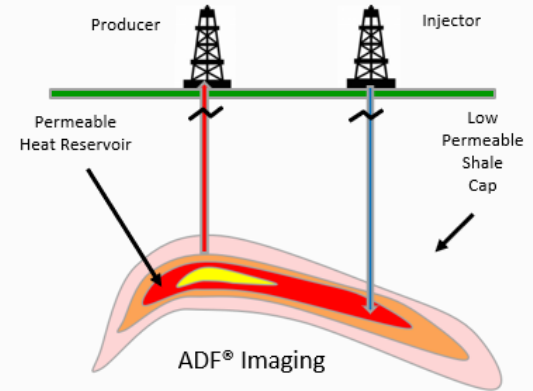
Apex has developed an analytical tool (ADF®) that can effectively identify highly permeable formations in the subsurface. The deeper and more consolidated the subsurface, the more effective ADF® works, which is EXACTLY what is needed.

Whilst standard seismic processing can provide detailed subsurface structure maps and some intrinsic properties, ADF® (using the SAME input seismic data) can identify areas of high permeability.

By contrast, areas of low permeability, such as a shale cap constraining the heat reservoir to a local area, do not light up with ADF® imaging.



Standard Seismic Data Processing can provide vital structural imaging....

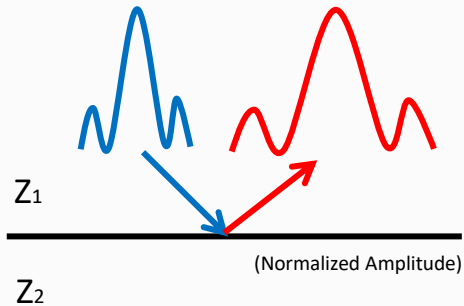


+ ADF® Processing can provide vital Perm and Fluid Mobility imaging

Apex and ADF[®].

Standard seismic data processing analyzes a series of reflections from subsurface layers and, subsequently (with a lot of math and manipulation), can build quite reliable structural images of the subsurface.

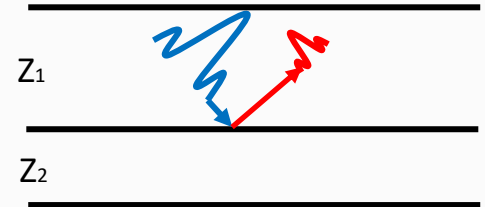
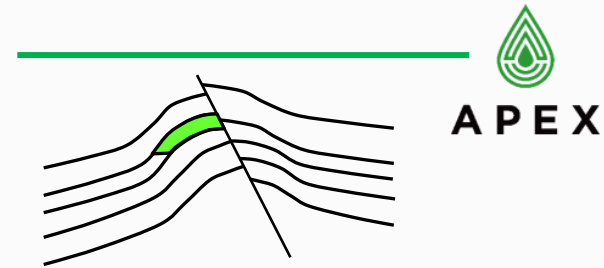
In general, the wavelet used in these analyses is considered stationary. That is, the reflected waves from the interface of two subsurface layers looks exactly like a smaller version of the incoming wave. The spread of frequencies is the same.



HOWEVER, in reality, when a subsurface layer is permeable and contains a fluid, the reflected wavelet from that layer has frequencies that travel at different velocities to the incoming wave. **The wavelet HAS changed.** The greater the fluid mobility (due to the type of fluid or the permeability of the layer), the greater the change to the reflected wavelet.

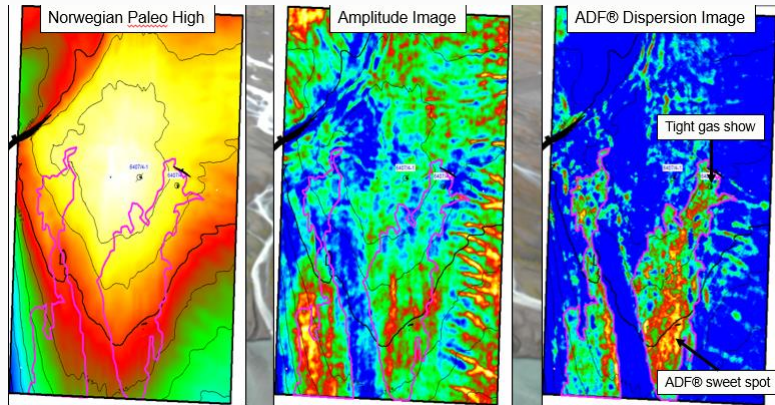
ADF[®] measures these changes and hence measures subsurface layers that contain different fluid type (for example Hydrocarbons) or those that permit fluids to flow through them easier (the layers have higher permeability).

The greater these changes, the greater the ADF[®] response.



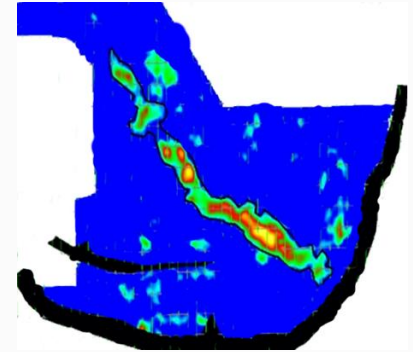
ADF® Examples

Not only can ADF® identify subsurface areas with higher permeability, it also has exceptionally high ‘plan-view’ resolution meaning the extent of the permeable reservoir can be better determined spatially, enabling engineers to design more efficient drilling programs AND identify permeable geologic bodies more conducive to optimum Hydrothermal use.



Norwegian North Sea:
Shale filled channel with overbank deposit clearly visible. .

Nile Delta:
HC Example: HC filled channel with hottest ADF® up-dip indicating greater fluid mobility due to lower chain hydrocarbons (gas).



And ALL of this can be done by simply reusing existing 3D Seismic Data initially acquired for Oil and Gas exploration, giving an old industry product a new and environmentally meaningful direction.

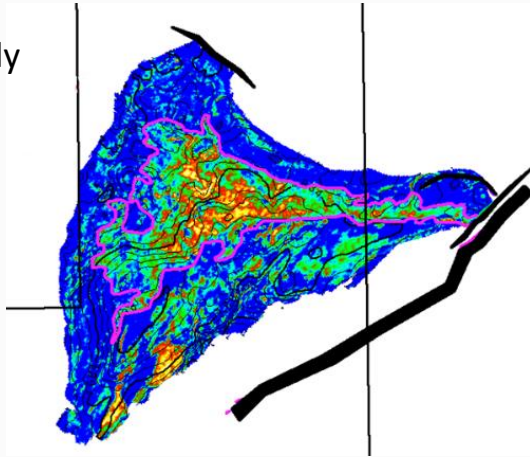
ADF[®] Examples – High Perm



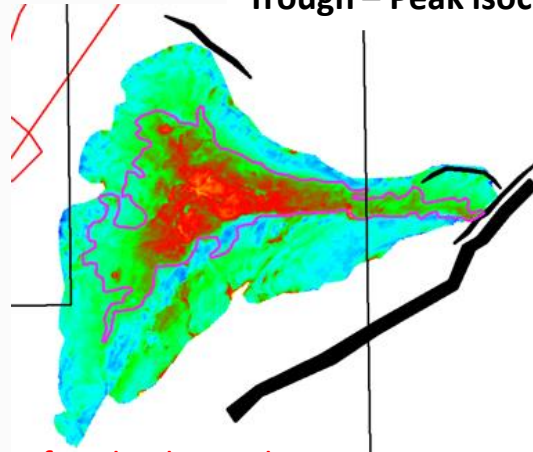
APEX

ADF[®] studies the effect of fluid movement on a seismic P-wave as it passes through the earth. The more permeable, the more fluid movement and the greater the ADF[®] measurement. Since the kind of reservoirs we are ideally looking at for Hydrothermal energy production are capped/enclosed by shales (very low permeable/tighter rock inhibiting the flow of liquids), the contrasting relatively high permeable areas stand out in the ADF[®] results.

Perm Geo-body
identified by
ADF[®]



Trough – Peak isochron



This isochron shows there's a correlation between the ADF[®] and Geo-body thickness.

Existing and future regions/targets for the development of Hydrothermal energy generation that already have 3D-seismic can therefore be significantly de-risked by the application of the Apex ADF[®] technology, hence decreasing cost and increasing commerciality of energy production.

Serendipity Pay, Co-Production and Putting old database information to good use...

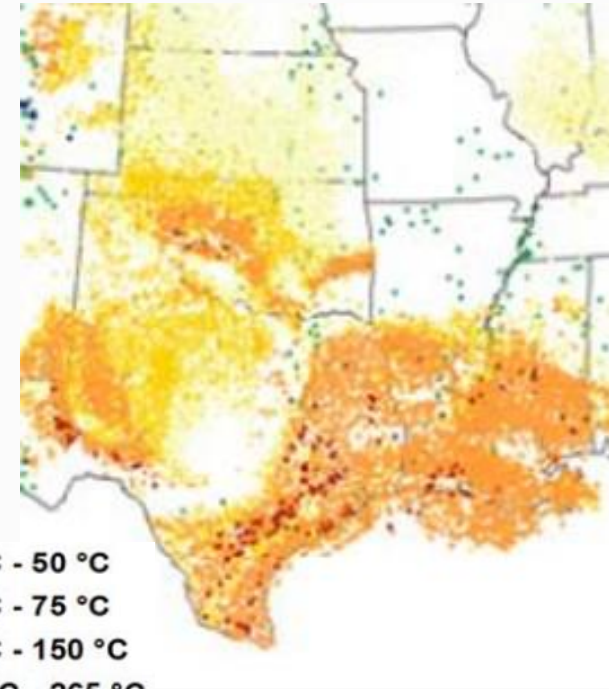


APEX

In 'Overlap' zones where there is both proven Hydrocarbon potential AND with targets that are deep enough (yet shallow enough) for commercial Hydrothermal production, drilling programs can be designed with duality in economic alternatives taken into account (additional de-risking process).

Whether the PRIMARY target is a permeable reservoir capable of sustaining long term viable Hydrothermal energy production (Dry or Flash Steam) OR a promising Hydrocarbon target, ADF[®] can effectively provide TWO BITES at the apple.

In areas where the subsurface temperature at target depth is already well known, ADF[®] can significantly help in de-risking the economics of 'new-target' drilling if Co-Production through Binary Cycle Power Plants is plausible (Again, ADF[®] will pick out the highest perm areas to drill and produce first). The Co-produced power can not only be used to reduce cost of hydrocarbon recovery operations, but excess power can be fed back into the grid for further profit.



AAPG 1972 BHT Well Temps.

SUMMARY



- ❖ Hydrothermal Energy is a sustainable renewable energy source.
- ❖ Hydrothermal Energy is a reliable energy source.
- ❖ Hydrothermal Energy CAN be made to be an extremely cost-effective energy source.

- ❖ Hydrothermal energy production efficiency depends upon target sub-surface permeability.
- ❖ It's expensive to drill and NOT find a permeable reservoir.
- ❖ Apex ADF® is an outstanding tool for identifying perm in the subsurface.
- ❖ The input to Apex ADF® is standard 3D Seismic Data.

- ❖ ADF® can identify the areal extent of high perm areas.
- ❖ ADF® interpretation can, under some conditions, identify relative thickness of high perm areas.

ADF® is therefore an excellent tool for:

- ❖ Primary Hydrothermal exploration.
- ❖ Primary Hydrocarbon exploration with a hydrothermal upside (or vice versa)
- ❖ Secondary development of existing fields and increasing Co-production efficiency.

For more information on Apex and ADF® visit our website at: www.apexspectral.com

End