GEOTHERMAL PLAY TYPING – THE DEVELOPMENT OF A MODERN CONCEPT FOR GEOTHERMAL RESOURCES ASSESSMENT

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ABSTRACT

The Play Type is a common concept in the exploration for subsurface natural commodities. A play type describes the generic geological environment that might host an economic accumulation of the commodity. The identification of a certain play type has therefore implications for exploration and extraction strategies. In geothermal exploration, a systematic worldwide play type concept is recently published. The aim of geothermal play typing is to streamline the exploration process, to define the play risk, and the chances of reservoir discovery by appropriate targeting and exploration methods, which are ideally geosystem specific. However the play type concept needs further definitions and specifications to integrate geothermal plays into the assessment process for geothermal resources. A worldwide usable language for the geothermal assessment process missing so far. First attempts have been made on a geothermal play type workshop under the umbrella of the IEA-Geothermal meeting in Vienna in May 2018. The recent nucleus for systematic research and conceptional activities is the first research project on geothermal play types, the PlayType project in Germany, funded by the Federal Ministry of Economics (BMWi). The results of the Vienna workshop reveal the common interest in the geothermal play type concepts but also the lacking clear definitions and play sub-categories. Play based exploration as a goal of geothermal resources assessment can only be achieved by continuous efforts on an international level.

Keywords: Geothermal plays, geological analogs, resources assessment, exploration chance, risk evaluation

1. GEOTHERMAL PLAY TYPE CONCEPT

One of the key elements in assessment, characterization and development of resources is the play type which has an almost mythical status among the oil and gas community – the successful play is thing of which legends are made, and playmakers are regarded as heroes of exploration and industry. While play concepts are clearly defined for hydrocarbon resources considering the source rock and petroleum charge system, the reservoir-seal formation and the trap type, worldwide applicable play concepts for deep geothermal resources are still lacking although industrial energy production from geothermal resources is as old as petroleum production. To address this deficit, a new geothermal play type catalog is developed based on geologic criteria (Moeck, 2014a). This geothermal play concept follows the basic approach of general resources assessment to group exploration targets according geologically controlled tiers,

connected by similar geodynamic, sedimentary, magmatic and/or tectonic evolution (Moeck, 2014b). With this new catalog of geothermal plays it will be ultimately possible to transfer lessons learned and applied technology among specific catalog types.

Analog to the petroleum play concept, that is defined by source rock-reservoir rock-regional seal or cap, a geothermal play can be defines as heat source-reservoir unit-thermal blanket or seal. Geothermal plays with a seal are blind while geothermal plays without seal are exposed with geothermal surface manifestations as hot springs, mud pools, steaming ground or gas exhalations.

2. THE EXISTING PLAY CATALOG

Key defining elements of the existing play type catalog are whether heat transfer is dominated by conduction or convection (Rybach, 1981), the characteristics of the heat source, and geologic controls on porosity-permeability structure. Whether convection or conduction dominates depends primarily on the characteristics of the heat source and the distribution of permeability within the host rocks at the system scale (Bogie et al., 2005; Lawless et al., 1995). It is important to recognize that convection and conduction are end-members of a heat transfer continuum, however, one mechanism may dominate the heat transfer.
Geothermal play types in convection-dominated systems are grouped into “Magmatic” and non-magmatic in “Fault-controlled in Extensional Domains” referring to the nature of the dominant heat source and tectonic setting (CV types in Fig. 1) (Moeck, 2014a).

Geologic controls of convection dominated systems are the presence and age of a magma chamber or intrusion, and the impact of faults on fluid flow. Three major convection dominated play types can be distinguished:

- Magmatic plays range from fields with active or recent magmatism as in volcanic fields to plutonic plays with quaternary intrusions associated with inactive or extinct magmatism. A magmatic geothermal play with an active or recent magmatic intrusion (CV1a) is distinguished by a shallow, intense heat source in the form of a young magma chamber.
- A Plutonic Geothermal Play (category CV2 in Fig. 1) incorporates a heat source in the form of a crystalline rock enriched in heat generating elements or a young, crystallized but still cooling, intrusive igneous body. This play type can co-exist with Magmatic play types, has elevated thermal gradients and is typically located along continent-continent convergent margins with recent plutonism.
- In an Extensional Domain Geothermal Play (category CV3 in Fig. 1) the mantle is elevated due to crustal extension and thinning. The elevated mantle provides the principal source of heat for geothermal systems associated with this Play Type. The resulting high thermal gradients facilitate the heating of meteoric water circulating through deep faults or permeable formations.

Conduction-dominated Geothermal Play Types can be thought of as ‘passive’ geothermal systems. They are commonly located at greater depth than convection-dominated plays (Moeck, 2014a). They can be

sub-divided according to the natural porosity–permeability ratio within the potential reservoir rock, related to diagenesis, lithology (deposition or petrogenesis), faulting, and the absence or presence of producible natural reservoir fluids.

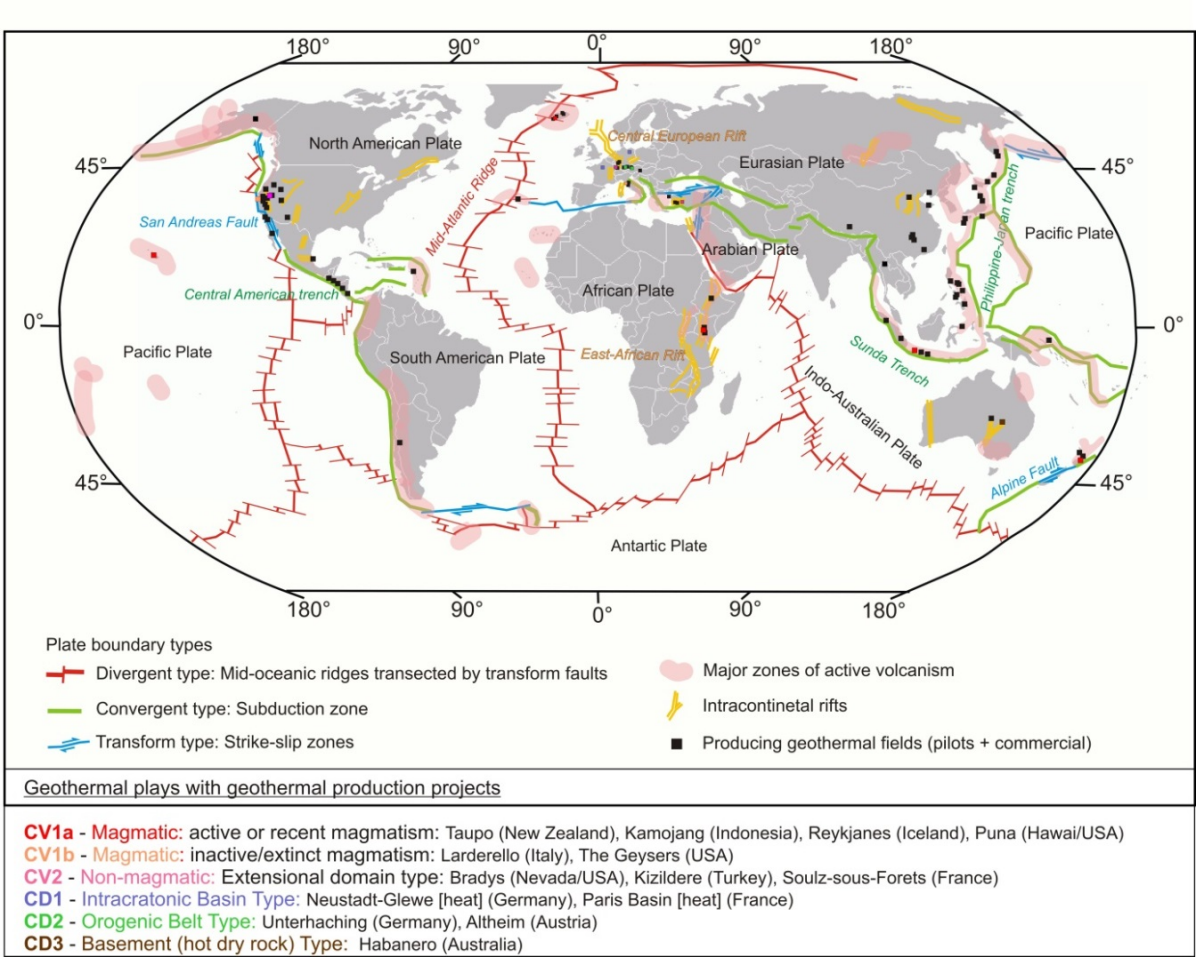

Fig. 1 Plate tectonic setting of installed geothermal systems worldwide with examples of Geothermal Play Types (Moeck, 2014b).

These Play Types dominate within intraplate, passive margin plate or orogenic belt settings where there has been no significant recent tectonism or volcanism. Hot sedimentary aquifers in basin environments may host predominantly hydrothermal resources while crystalline rock can host petrothermal resources.

The three major conduction dominated play types are:

- Intracratonic Basin Geothermal Play (category CD1 in Fig. 1) incorporates a reservoir within a sedimentary sequence laid down in an extensional or thermal sag basin. Intracratonic basins that originate from lithospheric thinning and subsidence are commonly divided into several troughs or sub-basins (Salley, 2000). Geothermal plays are located in different basin portions depending on the internal present-day structure of the basin and diagenetic or lithofacies effects on porosity and

permeability structure.

- An Orogenic Belt Geothermal Play (category CD2 in Fig. 1) incorporates a sedimentary reservoir within a foreland basin and orogenic mountain belt. The wedge shape of foreland basin results in a progressive deepening of potential aquifer rocks towards the orogen, with an associated increase in temperature. The downward bended formations are likely to host abundant hydrothermal resources. Prime targets are faults that originate from local extension during the flexural bending process.
- A Basement Geothermal Play (category CD3 in Fig. 1) is a faulted or fractured crystalline (usually granitic) rock with very low natural porosity and permeability but storing vast amounts of thermal energy. Such low porosity-low permeability rocks underlie large areas of continents but require reservoir development by EGS techniques to allow circulation between injector and producer wells using the hot rock mass as a heat exchanger (Cuenot et al., 2008). Brittle fault and fracture zones are prime exploration targets because they already contain some natural permeability.

3. THE MOST DEVELOPED GEOTHERMAL PLAYS

Worldwide, the majority of producing geothermal fields exploits magmatic play types (Moeck and Beardsmore, 2014). In the Americas and eastern Pacific, 46 magmatic/plutonic and two fault-controlled extensional domain plays host producing fields were recognized (Fig. 2, left). In the Asia and Pacific, 57 magmatic/plutonic, four extensional domains and two conduction dominated plays provide the resource for installed generating capacity (Fig. 2, center). Europe and Africa have the largest diversification of exploited play types: 36 plays are magmatic/plutonic type, 11 are extensional domain play type and 10 are conduction dominated (Fig. 2, right).

Moeck and Beardsmore (2014) did not catalog producing geothermal fields into their specific play types. However, even a preliminary cataloging of this sort can reveal which specific play types have predominantly been developed; what total generating capacity is related to which play type and which countries are pioneers in producing geothermal energy from conduction dominated plays.

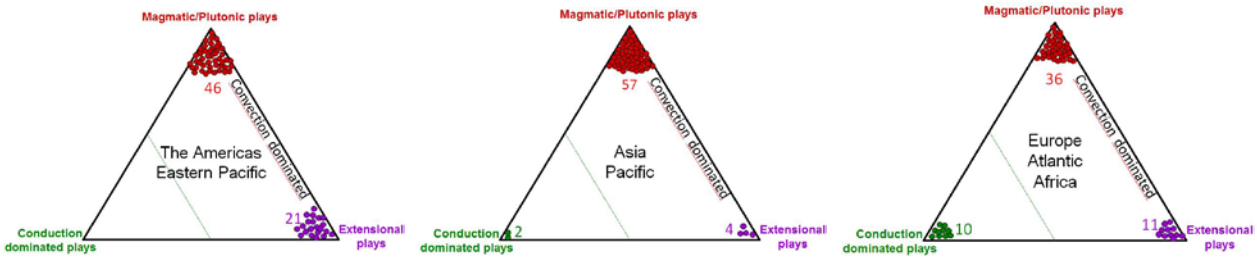

Fig. 2 Developed geothermal systems for power generation as shown in Figure 1, grouped into play type according to the play type catalog of Moeck (2014a)

Most of the geothermal fields fall neatly within a single play type, but some fields can be considered as hybrids. Only a few geothermal fields represent hybrid plays where the heat source is plutonic but the heat accumulation is also fault controlled in local extensional domains

4. IDENTIFICATION OF NEEDS AND GAPS

Although a general play type catalog exists, the key workflows in play typing, the terminologies of play characteristics, play subdivisions and play assessment including identification of play risk and play opportunity are still lacking or at least debated. Without the development of the play concept a systematic, unified and worldwide applicable assessment process for geothermal resources can hardly be achieved. First attempts on a further play concept development have been made at the IEA-Geothermal meeting in May 2018 in Vienna, addressing key questions in a geothermal play type workshop. European wide presenters from Hungary, Slovakia, Switzerland, Austria and Germany introduced the country specific geothermal plays, if play typing works, and what is needed to further develop and apply the play concept in terms of geothermal resources assessment and project risk evaluation. The presentations were completed by a comparison of geothermal and petroleum play typing, and how the play workflow for petroleum resources works.

The key conclusions of this workshop were:

- Comparison of geothermal targets belonging to one play type – accelerating the learning curve in exploration and exploitation, especially important for geothermal community where municipalities develop geothermal projects (in contrast to oil & gas, where global companies develop hydrocarbon assets)
- Play risk helps to decide if funding should be continued rising the question if a geothermal play works or if it does not work: High risk play types which did not work hitherto, would not be funded or are unlikely for investments
- Play types helps to streamline the exploration process because a certain workflow and play type specific exploration methods would be defined
- Existing play type catalog is geosystem wide. The play is however on a local scale (in the scale of license area) controlled by geological constraints
- The thermal transport process in a geological system is one of the if not the most important factor in cataloging “play provinces”
- Advection (recharge – discharge pathways either faults or strata controlled) should be considered, not only convection and conduction.
- HC exploration process starts with the Analysis of the Basin. Geothermal exploration has much more than one geosystem. Geothermal resources can be located in almost every geosystem but is not located everywhere in a geosystem.

5. NEXT STEPS AND IMPLICATIONS FOR IEA-GEOTHERMAL

The requirements on a further development of the geothermal play concepts can obviously only achieved

by an continuous process which can ideally by conducted by the IEA-Geothermal working groups. The results from the IEA Geothermal working groups could be distributed to other internationally working groups as the IGA. However, a continuous process on workshops and groups meetings is necessary to discuss and define play specific terminologies. Next steps on the way of geothermal play development are:

- The advantage of the very recent play type concept for geothermal resources is now, to define one workflow and terminology based in IEA working groups.
- Geothermal plays have more variations because magmatic systems, plutonic systems, amagmatic systems, cratonal / basement systems and sedimentary basin systems are existing resulting in different thermal transport processes
- The 1st research project on geothermal play types has recently started in Germany funded by the Federal Energy Ministry. This project will be used as framework for the IEA working group 13-A1. The globally working company Storengy, subsidiary of Engie, is participating in this German play type project, called PlayType
- Terminology should be global, play typing and exploration process is a national task
- Play maps are required however the necessary terminology is missing: Play, play level, play province, etc.
- The exploration process and meaning of specific terminology from hydrocarbon exploration cannot be copied but should be used for a geothermal exploration workflow pattern
- Play typing aims to identify the spots in geosystems that are likely to host exploitable geothermal resources

6. CONCLUSIONS

The advantage of the existing geothermal play type catalog is that it allows the comparison of exploration and extraction strategies within similar plays around the world. This will accelerate progress down the learning curve in geothermal exploration, including for EGS developments. Further considerations of geological controls on heat accumulation and extraction might result in additions or modifications to this catalog. The play type concept, workflows on play typing and play based exploration need to be further developed and defined – efforts, which could and should be conducted by the IEA-Geothermal working groups in their continuous work on an international level.

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