Keynote 1

Speculations on a glass half full: Burial, exhumation and gas saturation in coalbed methane reservoirs

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Almost all organic matter begins to emit methane as soon it stops being part of an active organism. Peat, which is the precursor of coal, is prodigious in its methane production. With burial, peat is transformed into coal and, as is well documented, secondary biogenic methane forms from a team effort of bacteria and Archaea. With increased burial and temperature, coalification results in devolatilisation with further, and more vigorous, production of methane (i.e. thermogenic methane). Throughout these processes the seam may or may not hold its maximum potential of gas (which we will assume for the sake of this abstract to be methane). The level to which a coal is approaching its maximum gas holding potential is usually expressed in percentages and is termed gas saturation. The factors controlling gas saturation in a coal seam are not well understood as evidenced by a general inability to predict it.

Bacteria and Archaea are highly sensitive to conditions such as temperature, pH, surface area and organic matter type (Gilcrease and Shurr, 2007; Green et al., 2008). Thus, it is not surprising that biogenic coalbed methane (CBM) plays are often variable in their gas saturation content. Even within a single seam, different vertical intervals can have a wide range of saturations (Mares et al., 2009). Some studies have shown that at the edges of basins where groundwater recharge is active that secondary biogenic gas formation can occur, which increases overall gas saturation, even in CBM plays of high rank (Ayes, 2002; Pashin, 2010).

In theory, CBM plays composed of thermogenic gas should almost always be at or near complete saturation. Yet, there are numerous examples of high rank CBM reservoirs that are undersaturated (Ayes, 2002; Kędzior, 2011). One explanation is loss of gas as a result of proximity to the surface during exhumation but where the interval has been later re-buried (Kędzior, 2011). Other undersaturated reservoirs are harder to interpret. For example, the Late Cretaceous to early Paleogene Guaduas Formation in Colombia has abundant high rank coal but with extremely variable gas saturation (Mojica and Mariño, 2013).

An explanation that is sometimes used to explain low saturation in CBM plays is where a reservoir has been buried to such a depth that the gas holding capacity decreases with a result that gas will be expelled. Upon later uplift, gas holding capacity increases (as a result of decrease in temperature), but since the gas charge does not, the reservoir is undersaturated (I'Anson et al., 2017; Moore, 2012). However, Bustin and Bustin (2008) suggest that this sort of explanation does not stand up to scrutiny. They present a convincing case that seems to demonstrate that with uplift, decreasing pressure will compensate for any lowering of temperature and concomitant increase in sorption capacity. Instead, gas holding capacity will decrease with the loss of pressure and result in a reservoir that remains fully saturated.

The Walloons Subgroup (Jurassic) in the Surat Basin (Australia) provides an additional clue to undersaturation in CBM reservoirs. There is a well-documented parabolic trend (increasing then decreasing) in gas content and saturation from top to bottom of the coal measures (Hamilton et al., 2012). Although a number of explanations for this trend have been suggested, what has not been noted previously is a slight, but significant increase in the rate of rank increase correlative with the most undersaturated basal coal zone. Because carbon materials have low heat conductivity (Cercone et al., 1996), the base of these coal measures will have experienced higher temperatures than the overlying strata as a result of a high geothermal gradient (Moore and Morris, 2018). The effect of the higher heat is manifest in the higher vitrinite reflectance values (a 'hocky stick' trend). The implication is that these basal coals were saturated at a lower rank (with lower gas holding capacities), expelled gas as a result of higher temperatures with depth, but, crucially, also experienced an increase of rank. Even with the increase in rank, these coals may not quite be in the thermogenic gas producing range. Thus, no new gas would have been generated through coalification processes but when uplifted, gas saturation would be measured against a higher adsorption curve relative to the pre-rank-increase curve. In essence the saturation goal posts were moved and even with a decrease in pressure (from uplift), these coal zones may struggle to remain fully saturated.

In conclusion, controls on gas saturation in CBM reservoirs, whether biogenic or thermogenically-derived, remain fruitful grounds for research. Indeed, considering its implications on gas production and commerciality (Moore and Zarrouk, 2011; Zheng et al., 2011), it is surprizing that more work has not yet been completed.

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Keynote 2

Mineral matter in coal: friend or foe?

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The occurrence of mineral matter in coal is usually regarded as having deleterious effects in coal utilisation. During mining, mineral matter may result in frictional ignition of methane and clays may give rise to handling problems during coal preparation and transport. The principal use of coal is for electricity generation and mineral matter may give rise to potentially serious problems in boiler operation. Abrasive minerals such as quartz may lead to increased wear of grinding mills and erosion of boiler tubes. Minerals such as pyrite and calcite may give rise to ashdeposition issues such as slagging and fouling which may be so severe as to require shutdown of the boiler. High chlorine contents may results in increased corrosion of boiler tubes. In fluidised bed combustors, the occurrence of low melting temperature mineral may lead to bed agglomeration and collapse of the fluidised bed resulting in boiler shutdown.

Mineral matter may have beneficial or adverse effect on coal gasification. Slag viscosity is a critical parameter in the operation of slagging gasifiers. If the critical viscosity is too high, fluxing agents may need to be added, increasing the cost of the operation. Conversely if the viscosity is too low a protective slag coating will not form on the walls of the gasifier and increased erosion of the tap hole may also occur. In Lurgi gasifiers, the occurrence of low melting point minerals may result in ash handling issues, possibly leading to shutdown of the gasifier.

In coke making, elevated phosphorus and sulphur contents, due to the occurrence of minerals such as apatite and pyrite, result in production of poor quality iron. The conversion of quartz to cristobalite in the coke may result in fracturing and weakening of the coke. Calcium and iron bearing minerals may also affect coke reactivity.

During coal liquefaction, abrasive minerals may lead to increased wear of the coal slurry pumps. However, clays such as smectite may have a beneficial cracking effect on the liquefaction product and iron sulphides are known to catalyse the liquefaction process.