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Quartz Cementation in Sandstones: Reappraising the Controls

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Quartz cementation, seemingly a mineralogically and texturally uncomplicated process, has led to interesting disputes in recent years. The old allochemical models, linked to large-scale fluid flow, were superseded by simpler isochemical models. These latter models have been pushed to the point of predictive capability, at least partly because they may be linked to basin modelling. All models require assumptions and simplifications. Problems and disputes have arisen with the isochemical models since some of the assumptions and simplifications, essential to facilitate quartz cement prediction, have been treated as being fundamentally true. Some of the assumptions that have been employed are listed in Table 1 with an assessment of their veracity.

The move away from descriptive allochemical models to quantitative isochemical models is to be applauded but only if the assumptions involved in quantification are constantly reappraised. The drive to quantification has led to many older precepts being either ignored or actively challenged. Some of the assumptions seem to have become articles of faith that are followed regardless of substantial bodies of evidence. Scientific hegemony of a model or approach is only welcome if all assumptions and their corollaries can withstand constant examination.

Thus it is held that since quartz grains in oilfields are assumed to be water wet, and since it is assumed that quartz cementation is rate limited by precipitation, then quartz cementation must not be inhibited in oilfields. Well-documented case studies prove that this is corollary is incorrect.

The initial fabrication of quartz cementation growth rates involved an assumption that quartz growth was continuous from the time-equivalent of the lowest fluid inclusion temperature through to the present day, irrespective of gaps in the temperature record. The assumption may be reasonable but it is now commonly held that quartz growth *must* be continuous since the models tend to produce the right answer. The possibility of episodic but transiently faster quartz growth is now ignored even though it would lead to quite different kinetic output.

Chemical compaction was formerly known as pressure dissolution but the role of effective stress in intergranular dissolution has been questioned recently and temperature alone (±mica crystals at grain boundaries) has been assumed to drive chemical compaction. An interesting hypothetical spin-off of the temperature-driven chemical compaction model is that basin subsidence may be the result of heating and not increasing effective stress. However, it now seems as if effective stress is a prerequisite for intergranular dissolution since there is no real alternative chemical driving force. Basin subsidence due to heating remains a bizarre corollary of models that ignore effective stress.

There remain many possible sources of quartz cement in sedimentary basins (Figure 1). While it is possible that internal sources dominate the budget, there are still the supply and transport steps to consider as well precipitation. While silica may be locally sourced, influx of fluids may drive silica-release reactions. Addition of oil will influence the rates of processes but local wettability will always be an important control on the rate of quartz cement growth. Quartz growth maybe continuous or episodic – the case is not yet proven.

Table 1 listing some of the assumptions used in modelling quartz cementation

Assumption	Proven, reasonable, false or unresolved?
All quartz cement is derived from intergranular pressure dissolution	Unresolved still since many quartz cemented sandstones seemingly are devoid of textures associated with pressure dissolution and there are many candidate sources of SiO_2 both internal and external to sandstones.
The rate of quartz cementation is controlled by the rate of precipitation	Unresolved since alternative rates have been proposed that seemingly fit empirical data. Occurrence of grain coating materials that limited quartz growth lends good support to rate control being true in at least some cases though.
Grain coatings can inhibit quartz cement growth	At least partly true although the presence of duct rims and minerals trapped at grain-cement boundaries suggests that not all grain coats stop quartz growth.
Temperature is the main control on the rate of quartz cementation	At least partly true as demonstrated by numerous large databases. Rates of all component processes in quartz cementation are faster as temperature increases. Temperature increase alone cannot easily drive quartz cementation though.
Quartz cementation operates continuously during burial until all pores are filled	Unresolved. Fluid inclusion data from quartz seldom has all temperatures represented; some interpret this as episodic growth, others assume gaps in temperature record are simple statistical anomalies from a record of semi-continuous growth. Ignores many interpreted paragenetic sequences that have punctuated quartz growth. May ignore some CL zoning evidence.
Pressure plays no role in quartz cementation	Contentious but potentially far-reaching assumption. Intergranular effective stress gradient recently shown to be essential – temperature alone cannot drive pressure dissolution
Mica at quartz-quartz boundaries drives silica diffusion	Unproven and contentious. Mica may enhance the rate of intergranular diffusion but it has not been proven to drive chemical compaction. Transient disequilibrium effects due to mica at boundaries can have but a limited long term effect on silica budget.
Quartz is water-wet in all oilfield sandstones and quartz grains always have a thick water-film.	Unproven. Most oil fields have mixed wettability. Moreover, water films on grains can be very thin. Irreducible water saturation at the crests of fields may lead to an insignificant water film thickness at grain-grain contacts.
Addition of oil to a sandstone has negligible effect on the rate of quartz cementation	Unproven and with a substantial body of evidence to refute this. Many oil fields have elevated porosity and reduced quantities of quartz cement at the crests of structures. Occurrence of oil filled inclusions suggests some growth is possible in presence of oil although no hint that quartz growth continues at low water saturations.

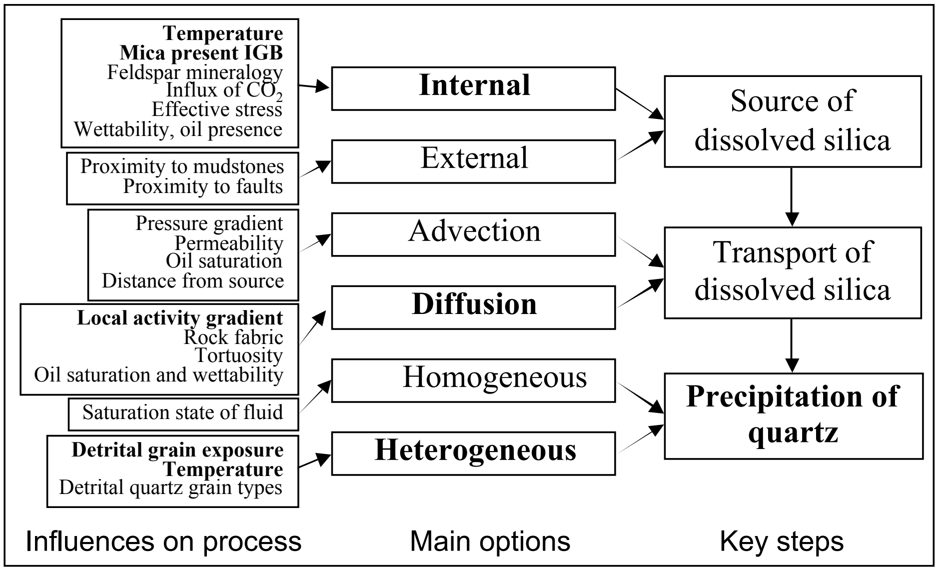

Figure 1: Detailing the key steps, the main options influencing the steps and some intrinsic controls that influence the process of quartz cementation. The bold items represent commonly assumed controls.