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# Geologic Evidence for and Characteristics of Fluid Seepage in Ancient Hydrocarbon-Seep Deposits

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To date, > 20 fossil hydrocarbon-seep carbonate occurrences of Devonian to Pleistocene age have been identified in the stratigraphic record worldwide, based on tectono-stratigraphic setting, and structural, sedimentologic, paleontologic and stable isotopic criteria. Occurrences range in size and volume, from singular, small, isolated authigenic carbonate deposits, to thousands of mounds of the same age dotted along lineaments within an ancient sedimentary basin. Both near-surface and subsurface paleoseeps are recognized. Relative position of the paleo-sea floor is obtained using fossils, and geometry of carbonate mounds, lenses or pipes with respect to surrounding fine-grained siliciclastic deposits.

Regional mechanisms for ancient fluid-flow are preserved, including association with grabens, joint systems, and synsedimentary faults. In addition, some paleoseeps are affiliated with ancient sedimentary serpentinites that mark dewatering of subjacent ophiolites, tectonosomes (mélange), or possible paleo-gas hydrates. Some allochthonous deposits occur in stratigraphic relationship with olistostromes. Local geologic evidence for paleo-fluid flow consists of concentric, cement-lined conduits, carbonate chimneys, subvertical pipes beneath carbonate mounds, preferred lithologic and structural pathways of cementation, and brecciation followed by cementation.

Textural and geochemical data confirm that changes in relative seepage rates (passive vs. active flow) occurred during the birth, development and shut-down of ancient seep mounds. Fluids also varied in pH, and in major and trace element content, as indicated by complex paragenetic sequences for some deposits, several of which exhibit a recurring cement stratigraphy. After cessation of hydrocarbon seepage, those mounds that remained at the seafloor display mound-top corrosion, borings, or establishment of hardground communities of invertebrates (e.g. solitary coral, crinoids). Over time, most Paleozoic and Mesozoic seafloor paleoseeps were buried and their pore spaces occluded by late diagenetic carbonate and/or sulfate mineralization. Tertiary to Recent paleoseep carbonates tend to show a more simplified cement sequence, and their $\delta^{13}C$-$\delta^{18}O$ values generally differ from rather than overlap with those of older deposits.