Tuesday, September 17, 2019

Southwestern Energy Conference Center, 10000 Energy Drive, Spring, TX 77389
Social 11:15 a.m., Luncheon 11:30 a.m.

Cost: $35 Preregistered members; $40 non-members/walk-ups

To guarantee a seat, pre-register on the HGS website & pre-pay by credit card.
Pre-registration without payment will not be accepted.
Walk-ups may pay at the door if extra seats are available.

If you are an Active or Associate Member who is unemployed and would like to attend this meeting, please call the HGS office for a discounted registration cost. We are also seeking members to volunteer at the registration desk for this and other events.

Lucy T. Ko
Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin

Facies, Depositional Environments, Chemostratigraphy, and Reservoir Quality of the Middle Devonian Marcellus Formation, Appalachian Basin, Northeastern Pennsylvania

Subsurface variation in facies is a main control on reservoir quality and can potentially be related to production. Previous studies of the Marcellus Shale have focused on the regional sequence stratigraphy and depositional models based on outcrops, wireline logs, and subsurface cores. A detailed sedimentological analysis was performed on one complete section of Marcellus core (310 ft) from northeastern Pennsylvania, consisting of core description, petrography (69 thin sections) and high-resolution geochemical analyses (every 2-inch), to better understand depositional processes and conditions and to characterize the vertical heterogeneity of the lithofacies that affect petrophysical and geomechanical rock properties. In addition, pore systems were systematically investigated in these core samples which are at near 3.0% R_o thermal maturity. Variations in biota, sedimentary structures, bioturbation, organic matter type and content, as well as sizes of pyrite framboids were integrated with geochemical data to define conditions at the sediment-water interface and within the water column. Fourteen lithofacies were defined on the basis of mineralogy, fabric, texture, and biota. The Marcellus Shale in northeastern Pennsylvania is interpreted to have been deposited in distal, relatively deep areas of the basin. Evidence of weak turbidity currents and bottom-water currents has been observed in the form of graded beds, multiple erosional surfaces, and thin-grain-supported silt laminae. Elevated concentrations of redox-sensitive and productivity-sensitive trace elements (U, Mo, V, Cr, Ni) in the basal shale member suggest deposition under reducing, sulfur-rich (anoxic to euxinic) conditions during times of elevated productivity. An upward decline in organic richness and trace-element abundance was observed, likely due to an increase in dilution and more oxygenated water column through time. The abundance of small conical calcitic shells—including tentaculitids and styliolinids—is significantly higher in the Cherry Valley member. The high abundance of algal cysts (*Tasmanites*)

HGS Northsiders Luncheon *continued on page 26*

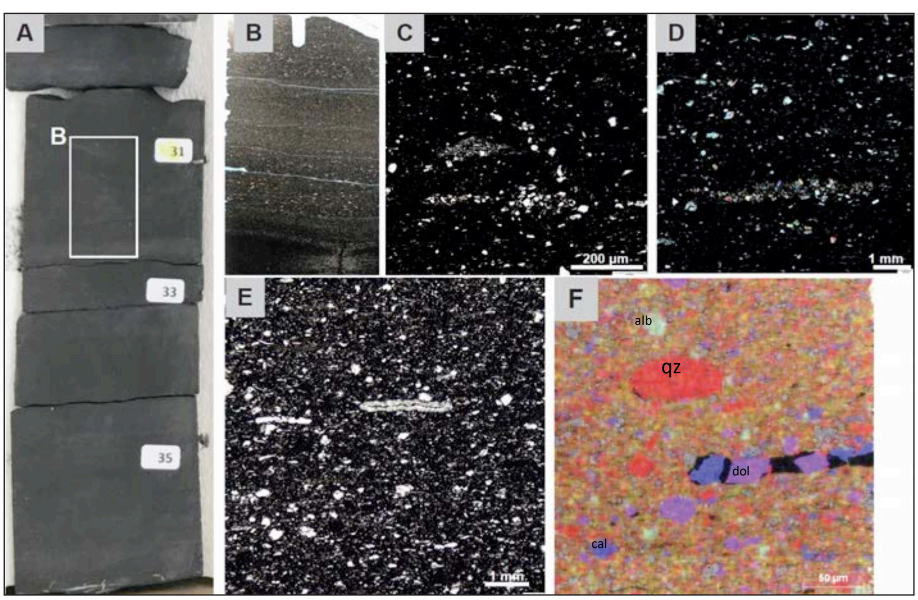

Figure 1. *Core and thin-section photographs of the massive to faintly laminated argillaceous siliceous mudstone facies in the BMS at the depth of 8099.92 ft. (A) Massive, no apparent lamination on the core surface. (B) Thin section scan of the area inside the white box in A. Lamination is formed by alternating fine-silt laminae and agglutinated-foraminifera-bearing laminae. (C) Agglutinated foraminifer and randomly distributed silt. (D) Agglutinated foraminifer is composed primarily of calcite silts. (E) A collapsed* Tasmanites *cyst and large agglutinate foram with mixed silica and carbonate mineralogy. (F) SEM-EDS map show the matrix texture and mineralogy. qz: quartz; cal: calcite; dol: dolomite; alb: albite.*

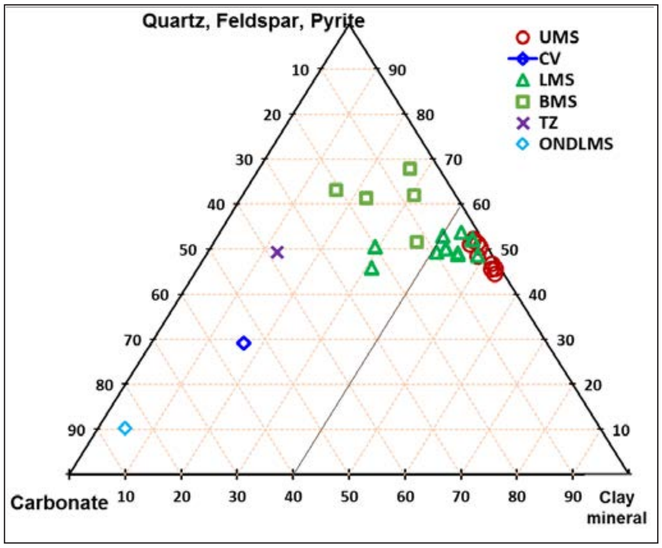

Figure 2. *Ternary plot of mineralogy based on X-ray diffraction (XRD) analysis of the studied Marcellus Formation samples. UMS = Upper Marcellus Shale member; CV = Cherry Valley Limestone member; LMS = Lower Marcellus Shale member; BMS = Base Marcellus Shale member; TZ = Transition Zone; ONDLMS = Onondaga Limestone. Marcellus Formation is mostly siliciclastic mudstone. Upper and Lower Marcellus members are more argillaceous than the Base Marcellus member which is more siliceous.*

in the basal Marcellus shale is correlative with the highest sulfur and TOC concentrations, representing an anomalous period of intense phytoplankton growth in the Appalachian Basin caused by additional nutrients, possibly from wind or rivers. The algal cysts bloom increased organic input and enhanced the production of organic matter (OM) (**Figure 1**). The basal Marcellus Shale (BMS) that is dominated by laminated *radiolarian* and *Tasmanites*-rich argillaceous siliceous mudstone facies has the best reservoir quality (highest TOC, OM porosity, and lowest clay mineral content).

Both SEM and HIM imaging reveal that OM spongy pores whose sizes are mostly < 200 nm are predominant. Mineral pores are present, many associated with carbonate dissolution. The majority of OM is pyrobitumen which hosts spongy pores. Correlative relationships between total organic carbon (TOC) and porosity (R^2=0.5) and TOC and permeability (R^2=0.76) suggest that pyrobitumen and OM spongy pores form a connected network. The total porosity does not vary much throughout the Marcellus; however, the measured matrix permeability of the BMS is two orders of magnitude higher than that of the lower Marcellus Shale (LMS) and upper Marcellus Shale (UMS). The significant increase in permeability might be related to higher TOC, more Type II kerogen, and a less-compacted siliceous framework that helps preserve interparticle pores in the BMS than in the argillaceous framework in the LMS/UMS (**Figure 2**).

Biographical Sketch

Lucy Ko is a postdoctoral fellow at the University of Texas, Bureau of Economic Geology, specializing in unconventional reservoir characterization and geochemistry. She has been associated with the Mudrock System Research Laboratory (MSRL) for more than 5 years.

She received her MS degree from the Colorado School of Mines in 2011 and her PhD degree from the University of Texas at Austin in 2017. She has worked at Platte River Associates and interned at ConocoPhillips twice in the past.

She is passionate about multidisciplinary science and integration. She enjoys problem-solving, taking challenges, pursuing efficiency, and facilitating cross-discipline communication.