CURRICULUM VITAE

Charles L. Powell, II
Retired U.S. Geological Survey, (8/2015)
powell2@sbcglobal.net

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EDUCATION

- Fullerton Community College, Geology — A.A. Degree, 1976
- California State University, Fullerton, Geology
- San Jose State University, Geology — B.S. Degree, 1983
- San Jose State University, Geology — M.S. Degree, 1986

CURRENT RESEARCH INTERESTS

- Neogene chronostratigraphy and biogeography of the northeastern Pacific Ocean, specifically:
    - Miocene to Pleistocene marine paleontology and biostratigraphy of California
    - Invertebrate paleontology and biostratigraphy of the Southern California Bight
    - Evolution of the proto-Gulf of California through macro-fossils
    - Stratigraphy and invertebrate paleontology of the Neogene of central California
- Molluscan taxonomy (i.e., naming new species discovered during my nearly 40 years of working in the field.

SIGNIFICANT RESEARCH ACCOMPLISHMENTS

Statement - Basic age dating still forms the backbone of most geologic investigations. Since many rock units across the US and the world are still undated or poorly dated, basic paleontology is still in demand. Without the basis of geologic age the results of more in-depth studies from a multitude of geologic disciplines would be of questionable use. Also, the developing of new and refining previously developed biostratigrapies aids in dating marine rocks, even in areas previously studied in detail providing new insights. For example, new Quaternary dating in the Los Angeles Basin, an area well studied for over 150 years, are now being used to 1) model ground water and correlate aquifers in the Los Angeles Basin (also related are pollution studies and sea-water influx into ground water reservoirs); 2) determine uplift rates; and 3) determine fault movement models (including blind thrusts in the central Los Angeles Basin). Both of the latter are intrinsic to understanding geological hazards across southern

California. In addition many numerical dating techniques need basic paleontologic age determinations to calibrate their results.

Quaternary chronostratigraphy: *The chronozones being developed and refined allow geologists to determine a more precise age of Quaternary marine deposits in the field with a minimum of expense. See published report 27 below.*

I have identified five late Quaternary chronostratigraphic zones in southern California using marine molluscan faunas. In addition a sixth late Quaternary chronozone has been recognized in central California. From youngest to oldest they occur at (1) < 12,000, (2) 20,000 – 15,000, (3) 105,000(?) – approx. 40,000, (4) approx. 125,000, (5) approx. 350,000 - 150,000, and (6) approx. 600,000 - 300,000, years B.P. The fossil faunas studied show four biogeographic character states: (1) much cooler than present water temperatures; (2) slightly cooler than present water temperatures; (3) water temperatures similar to today; and (4) warmer than present water temperatures. These zones are not based on individual taxa or assemblages but on the biogeographic affinities of faunas with more than 25 molluscan taxa.

The chronozones are informally numbered from youngest to oldest. The fauna from chronozone 1 is essentially modern with no or very rare extra-limital taxa. Chronozone 2 has molluscan fauna suggesting much cooler water temperatures than present along the adjacent coast. Vertebrates from chronozone 2 suggest even cooler water temperatures than the mollusks. Faunas from chronozone 3 contain a significant percentage of north-ranging taxa and a few northern extra-limital taxa. Faunas from chronozone 4 contain a significant percentage of south-ranging taxa and a few southern extra-limital taxa, as well as occasional northern extra-limital taxa, which may be reworked. Chronozone 5 faunas show a higher percentage of south-ranging taxa and southern extra-limital taxa are moderately common. Chronozones 4 and 5 are similar faunally but can be differentiated by the percentage of south-ranging and southern extra-limital taxa. These chronozones are also easily identified using amino-acid racemization studies. Finally, faunas of chronozone 6 show both cool and warm water faunas and commonly contain a small percentage of extinct taxa. This chronozone will likely be further subdivided in the future.

The molluscan faunas used here are coupled with geomorphic, amino acid, and stratigraphic position to develop a stratigraphic sequence. This sequence is integrated with the stratigraphic ranges of extinct taxa and radiometrically dated faunas from both within and outside of southern California to date the chronozones.

Imperial Formation: *The Imperial Formation can be divided into two distinct units differing in rock type, provenance, age, paleogeography, and fauna. Also four major incursion of seawater into the Salton Trough are recognized. The oldest of these incursions shows normal marine conditions in the Gulf prior to the tectonic opening of the mouth of the Gulf of California. See published reports 4, 5, 6, and 16 below.*

My work shows that two distinct units are assigned to the Imperial Formation in southern California. I have informally divided the Imperial Formation outcrops into two units, "northern" for most Riverside County (Cabazon, Garnet Hill, Whitewater) exposures and "southern" for outcrops in Imperial and San Diego Counties, and at Willis Palms in Riverside County. These two informal units show differences in rock type, provenance of sediment, age, paleogeography, and molluscan macrofauna. Recent confusion about the Imperial Formation and its relation to other sedimentary units in the Salton Trough and elsewhere leads to suggest resserecting the name Lion Sandstone for most of the "northern" exposures and retaining the name Imperial Formation for the "southern" exposures.

Most of the northern exposures are considered Miocene in age based on mollusks, foraminifers, and radiometric and ash correlation age determinations (6 Ma above the Imperial Formation at Whitewater; 10 Ma below the Imperial Formation at Whitewater, and 8.0-7.6 Ma below the Imperial at Garnet Hill). Rocks in the lower part of the section at Whitewater are of obvious local provenance with sediment coming from the adjacent San Bernardino Mountains, although the basement is of the San Gabriel Mountains type. Rocks in the upper part of the section at Whitewater as at Cabazon, are too fine grained for provenance determination but are interlayered with stringers of conglomerate sandstone beds with clasts of Chocolate Mountains origin. Rocks from Garnet Hill exposures come from the San Jacinto Mountains. Mollusks from these northern outcrops show strong faunal ties with the Miocene Caribbean molluscan province, a tie that is not as strong in the fauna from the southern exposures. In the 1930's the Lion Sandstone (described from Cabazon) was correlated with, and included in, the type Imperial Formation based on supposed similar molluscan faunas. Recent studies of mollusks from these outcrops and in the southern area show that although the faunas have similarities, they can be easily distinguished.

Outcrops from the "southern" (type) Imperial Formation are considered Pliocene in age based on macrofauna, microfauna, and magnetostratigraphic data of earlier workers. These Imperial Formation rocks show local provenance from the adjacent Santa Rosa Mountains and Coyote Mountain. Mollusks, echinoids, and corals from these exposures show closer faunal ties to the modern Gulf of California than to the Caribbean province (modern or fossil).

Purisima Formation: *Major research contributions for this study include: 1) Correlation of various outcrops in scattered fault-bounded terrains by recognition of distinct molluscan faunas; 2) Refined age determination of the Purisima Formation in several of the fault-bounded blocks; and therefore 3) Correlation of outcrops allowing recognition of fault block and movement on faults. See publications 21 and 26 below.*

Sedimentary rocks more than 1.6 kilometers thick are attributed to the upper Miocene to upper Pliocene Purisima Formation in the greater San Francisco Bay area. These rocks occur as scattered, discontinuous outcrops from Point Reyes National Seashore in the north to south of Santa Cruz. Lithologic divisions of the Formation appear to be of local extent and are of

limited use in correlating over this broad area. The Purisima Formation occurs in several fault-bounded terraces, which demonstrate different stratigraphic histories and may be found to represent more than a single depositional basin.

I recognized three molluscan faunas, the La Honda, the Pillar Point, and the Santa Cruz, from USGS collections and published literature for the Purisima Formation. These biostratigraphically distinct faunas aid in the correlation of the scattered Purisima Formation outcrops. The lowermost La Honda fauna suggests shallow-water depths and an age of late Miocene to early Pliocene. This age is at odds with a younger age determination from an ash bed in the lower Purisima Formation along the central San Mateo County coast. The Pillar Point fauna contains only a single age diagnostic taxon, *Lituyapecten purisimaensis* (Arnold). This bivalve is reported as Pliocene in age, but it only occurs in the Purisima Formation, so its age here is an example of circular reasoning. However, based on tentative lithologic correlation this fauna may represent the same period of time as the upper part of the La Honda fauna. This fauna differs from either the La Honda or Santa Cruz faunas in that it represents significantly deeper water. As with the lowermost La Honda, the uppermost Santa Cruz fauna also suggests shallow-water depths and a possible age range of early to late Pliocene.

Wilson Grove Formation: *My work on fossil faunas from the Wilson Grove Formation (Sonoma County, California) (="Merced" Formation of authors) suggests: 1) The age of outcrops is older in the south and younger in the north; 2) Outcrops in the south represent deep water, in part, submarine fan environment; 3) Outcrops from the northern part of the outcrop area were deposited at shallow water depths and are younger than those to the south; 4) The Wilson Grove Formation covers an areas of where major faults "step-over" and can be used to determine the timing of movement on these faults; 5) The Formation ranges in age from latest Miocene to late Pliocene (previously thought to be Pliocene to Pleistocene); 6) The formation is substantially thicker than previously recorded; and 7) Outcrops of the Merced Formation at Bolinas, Marin Co., California, correlated in the past with the Wilson Grove Formation, are younger and correlate with the type Merced Formation (San Mateo Co., CA) and not the Purisima or Wilson Grove Formations.*

The Wilson Grove Formation is exposed as scattered outcrops from Petaluma north to northern Santa Rosa, and from the Rodgers Creek fault west to the San Andreas fault. A fauna of about 83 invertebrate taxa consisting of two brachiopods, 77 mollusks (40 bivalves and 36 gastropods), at least three arthropods, and at least one echinoid have been collected. Outcrops and fossils from the Wilson Grove Formation suggest continental shelf/slope environment to transitional marine/continental environments and range in age from late Miocene to late Pliocene.

Rocks and fossils suggesting a deep-water marine environment occur to the southwest along the Estero San Antonio. While at Meacham Hill, near the Stony Point Rock Quarry, and along the northern margin of the Wilson Grove Formation at River Road and the type locality the Wilson Grove Formation appear to have formed in a shallow marine to continental

environments. At Meacham Hill, these shallow water deposits suggest a brackish bay to continental environment, whereas at River Road and Wilson Grove, fossils suggest normal, euhaline conditions. Mollusks from the River Road area also suggest water temperatures slightly warmer than today along the nearby coast.

Outcrops in the central part of the outcrop area suggest an earlier age than outcrops to the northeast. The informal late Miocene Roblar tuff of Sarna-Wojcicki (1992) occurs at Steinbeck Ranch in the central portion of the outcrop area. Outcrops at Salmon Creek, northeast of Steinbeck Ranch, contain *Aulacofusus? recurva* (Gabb) and *Turcica brevis* Stewart, which both suggest a Pliocene age and *Searlesia portolaensis* (Arnold) which is known from the early Pliocene of central and northern California and into the late Pliocene in southern California. Fossil collections from along River Road, to the northeast, contain the bivalve mollusks *Macoma addicotti* (Nikas) and *Nuttallia jamesii* Roth and Naidu which suggest a late Pliocene age. The Roblar tuff of Sarna-Wojcicki (1992) also crops out to the northeast in the River Road area, where it is overlain by stratified marine sandstone and conglomeratic sandstone, including outcrops at the type locality.

Gubik Formation: *The Gubik Formation and its unnamed equivalents represent all latest Tertiary to Quaternary marine deposits in Alaska, north of the Aleutian Islands to the Canadian border. Preliminary work established a biostratigraphy for these deposits based on extant and extinct molluscan taxa.*

Work accomplished, mostly during the 1980's and early 1990's identified the occurrence of about 300 molluscan taxa from over 500 localities in Alaska (over 8,300 lots). These data, supplemented with radiometric and amino-acid dating, help establish faunal composition from eight marine transgressions, ranging in age from about 4 ka to < 3.5 Ma. Four of these transgressions can be recognized solely on the basis of their fossil fauna. This study was never finished and remains mostly unpublished.

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