Tectonophysics 502 (2011) 267–275

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Investigations of ground water flow associated with the Saratoga warm springs and the Tecopa Hot Springs near Death Valley, California, using magnetic and conductivity methods

Antony M. Wamalwa, Laura F. Serpa *, Diane I. Doser

Department of Geological Science, University of Texas at El Paso, El Paso, TX 79968, United States

ARTICLE INFO

Article history:
Received 13 May 2010
Received in revised form 30 November 2010
Accepted 3 December 2010
Available online 13 December 2010

Keywords:
Geophysics
Ground water
Death Valley
Hot springs
Magnetics
Conductivity

ABSTRACT

Electrical and ground magnetic surveys at Saratoga Springs and Tecopa Hot Springs in the vicinity of Death Valley reveal intersecting faults that appear to control the spring locations. Faults striking east–west and north–south intersect at Saratoga Springs. High electrical conductivity along imaged faults at Saratoga Springs implies shallow ground water channels between 5 and 20 m deep. Regions of high conductivity correlate with water saturated zones or clays. Gradients in magnetic and conductivity data at Saratoga are interpreted as faults. Similarly northwest- and northeast-trending faults are inferred to intersect at Isolated Spring in Tecopa Valley. Our data suggest that ground water flow along deep structures allows water to be heated and could account for the water temperature of about 41 °C at the Springs at Bath in Tecopa Valley. However, we hypothesize that cold water from the Amargosa River percolates downward and mixes with hot water rising at the fault intersections. The river water accounts for the lower water temperatures at Saratoga and at the Isolated Spring as compared to the Spring at Bath in Tecopa Valley.

1. Introduction

The study of ground water distribution in the vicinity of Death Valley, California is challenging (Hunt et al., 1966; Miller, 1977; Belcher et al., 2001, 2002) because Death Valley and the nearby Tecopa Valley receive only 5 cm/yr rainfall on average but both have abundant flowing springs. Numerical inter-basin ground water flow modeling and geochemical analysis of the water in the numerous springs suggest a distant source outside the Death Valley region (Hunt and Robinson, 1960; Steinkampf and Werrell, 2001; Winograd et al., 1985; Davisson et al., 1999; Nelson et al., 2001; Miner et al., 2007). The water traverses numerous faults in this region to the spring sites (Faunt, 1997). Inter-basin ground water flow from the Amargosa Desert to Furnace Creek south of the Funeral Mountain has been proposed (Anderson et al., 2006). On the other hand, Davisson et al. (1999) advocated for a north–south ground water flow rather than an east–west flow. Nevertheless it is believed that the source of the spring waters at the Tecopa Valley and Death Valley is the Spring Mountains in nearby Nevada (Larsen et al., 2001; Miller, 1977; Nelson et al., 2001; Sperry and Larsen, 2007; Sperry, 2008). Water is transported along underground aquifers that are inferred to consist of interconnected porous sediments as well as fractures and faults in the bedrock (Hunt et al., 1966; Hunt and Robinson, 1960; Miller, 1977). The water may be heated during transport but the locations and the temperature variations of the springs across the region do not appear to reflect a simple pattern of deep circulation (Steinkampf and Werrell, 2001; Nelson et al., 2001).

In this study, we investigate the geologic and structural controls on the springs' locations. In particular, we use magnetic and resistivity data to investigate Saratoga Springs in southern Death Valley and Isolated hot springs in the Tecopa Valley, southeast of Death Valley. Saratoga Springs is a warm spring with water temperatures of about 28 °C located nearly 100 km from the Spring Mountains while the Isolated Spring with water temperatures of about 42 °C is located in Tecopa and is only about 70 km from the putative source region as shown in Table 1 (Sperry, 2008; Steinkampf and Werrell, 2001). Water discharging at the Saratoga Springs in Death Valley may share the same source, the Spring Mountain, with the water from springs in Tecopa Valley, for example, the Tecopa Hot Springs (Grimshaw, Isolated and Springs at Bath) as suggested by Hunt et al. (1966) and Larsen (2000). The travel path to Saratoga Springs is significantly longer than the path to Tecopa Springs and in the model proposed by Mifflin (1988), it is expected that the water would be hotter at Saratoga than at Tecopa if it continues to travel along a deep path (Morrison, 1999; Steinkampf and Werrell, 2001). However the water at Saratoga is 13 °C colder than the water at the Springs at Bath in Tecopa Valley.

Our study indicates that intersecting normal faults may be the key to the location of these springs. We hypothesize that the orientation of the intersecting faults relative to the regional stress field in Death Valley, in particular, produces open fractures that act as a conduit for the rising hot

* Corresponding author. Tel.: +1 9157476085.
E-mail address: lfserpa@utep.edu (L.F. Serpa).

0040-1951/$ – see front matter
doi:10.1016/j.tecto.2010.12.001

Table 1
The location of some of the springs in the Death Valley and Tecopa Valley regions with their water temperatures and pH.
Extracted from Steinkampf and Werrell (2001) and Sperry (2008).

Springs	Latitude	Longitude	pH	Temperature °C
Tecopa Hot Springs at Bath	N 35°52′19″	W 116°13′46.8″	7.82	46.9
Isolated Springs	N 35°52′24.6″	W 116°13′15.6″	7.06	41.6
Grimshaw Springs	N 35°53′7.0″	W 116°13′52.2″	8.31	45.5
Saratoga Springs	N 35°40′53″	W 116°25′18″	7.71	28.3

water. The water temperature and chemistry between Tecopa Hot Springs and Saratoga Springs and other springs in Tecopa Valley and Death Valley have been discussed by various researchers (e.g. Larsen et al., 2001; Nelson et al., 2001; Steinkampf and Werrell, 2001; Davisson et al., 1999; Miner et al., 2007). Thus understanding the contribution of local and regional geologic structures may answer some questions on the origin and distribution of ground water in this region.

2. Regional hydrology, geology and tectonics

Death Valley (Fig. 1) is a northwest-trending pull-apart basin (Burchfiel and Stewart, 1966; Hill and Troxel, 1966; Miller and Wright, 2004) in the southwestern Great Basin with an average rainfall of 5 cm/yr (Steinkampf and Werrell, 2001). It includes the lowest point in the western hemisphere and is the drainage sink for much of the nearby region. The valley is bounded on the east by the Black Mountains and on the west by the Panamint Mountains. The Furnace Creek, Garlock, and Death Valley fault zones are major strike-slip faults associated with the transtension that formed the valley (Hill and Troxel, 1966; Guest et al., 2003; Serpa and Pavlis, 1996; Serpa, 1990).

The geology of the Death Valley region is marked by folded and faulted Proterozoic to Paleozoic rocks that include the Proterozoic basement and an overlying Miogeoclinal sedimentary section that was subjected to Mesozoic thrusting and Cenozoic extension (Belcher et al., 2002; Butler, 1988; Hunt and Mabey, 1966). Some of the rocks have low inter-granular porosity; particularly crystalline basement but also the Miogeoclinal cover which was variably metamorphosed

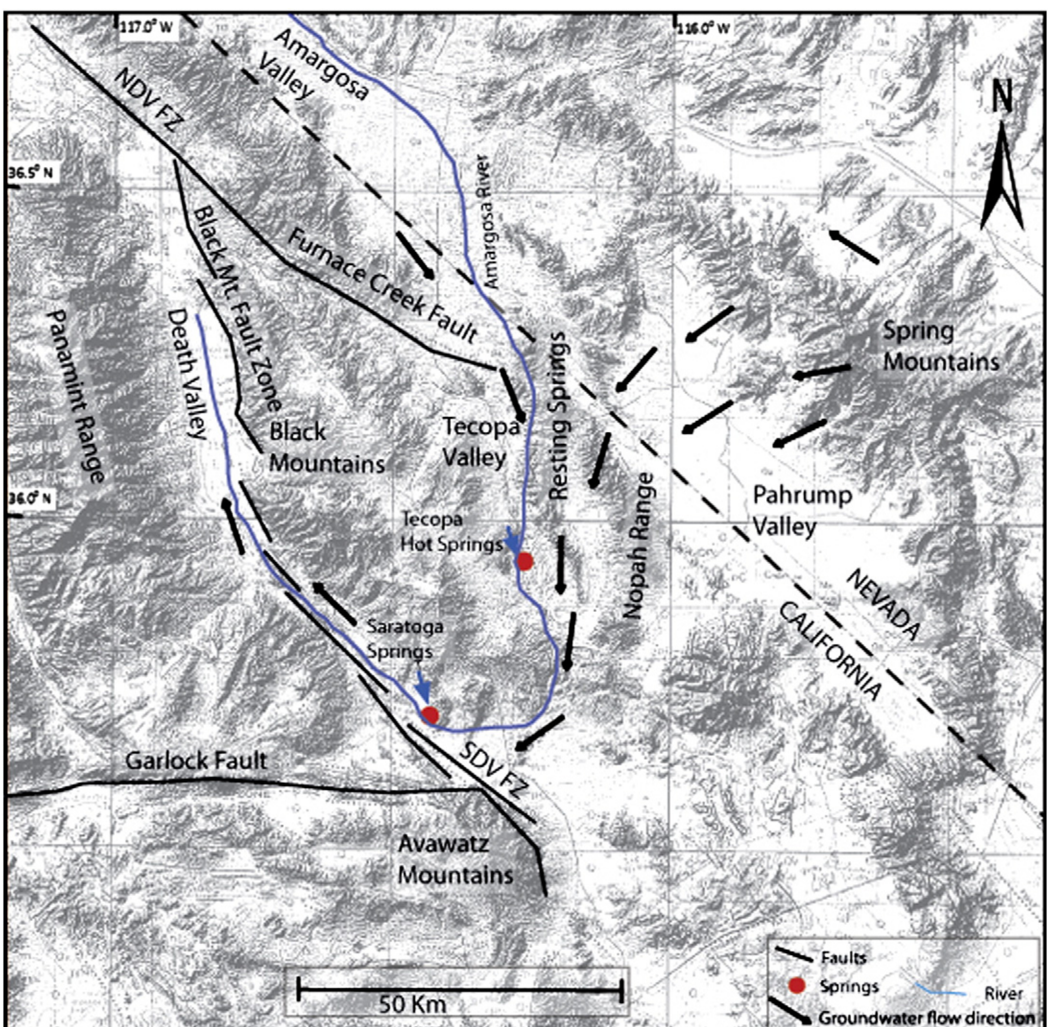

Fig. 1. Death Valley regional map showing major fault zones: Furnace Creek Fault, Southern Death Valley Fault Zone (SDV FZ), Northern Death Valley Fault Zone (NDV FZ), Garlock Fault. The red circles are the locations of Saratoga and Tecopa Hot Springs.
Modified from Morrison (1999) and Blakely et al. (1999).