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Hydrogeochemical features and groundwater renewal rate estimates from deep aquifers in the Pampean plain, Córdoba province, Argentina

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ABSTRACT

In the Córdoba Province (Argentina), people use groundwater from confined aquifers systems (CAS) for different activities (irrigation, livestock, etc.). Therefore, comprehensive studies for a more sustainable use of these resources are necessary. The aim of this study is to assess the geochemistry, the water flow dynamic and the renewal rates of groundwater in the CAS of the Pampean plain of Córdoba. The CAS evaluated in this study are composed of two multilayered subsystems (A1 CAS and A2 CAS) of variable extent formed by thin (3–8 m) sand-pebble lenses. The subsystems are associated with Neogene fluvial palaeosystems. These layers are situated at different depths (120–400 m) and are interbedded with thick clay strata, which generate different confinement grades. Groundwater is fresh and of good quality (EC $<$ 2.000 μS/cm) because the geochemical processes that allow the transference of ions into solution are diminished by the grain size (sand and gravel) and the aquifer sediment mineralogy (quartz prevailing). A2 CAS has the best water and higher hydraulic conductivity resulting from coarser textures. The main geochemical processes that influence CAS groundwater composition are silicate weathering, carbonate dissolution, cation exchange and atmospheric input. The interpretations made from geochemistry, isotopes (^{2}H,^{18}O,^{3}H and ^{14}C) and hydraulic results, demonstrate that these systems are recharged in the piedmont areas and have groundwater ages from hundreds to thousands of years, that is, groundwater recharged during the Holocene. Even though the CAS are currently used for irrigation, no significant decreases are observed in groundwater levels. This situation would indicate that these systems are not yet being over-exploited.

1. Introduction

Groundwater studies require integral and holistic research using many different tools (geological, geomorphological, geochemical, stratigraphic, isotopic, etc.). Using them, various evidence can be obtained that contributes to a better understanding of a regional hydrogeological behaviour, an important and vital basis for groundwater management. The resolution of a large number of different groundwater problems (contamination, overexploitation in irrigation areas, among others) requires improvement in the understanding of the geochemistry, water flow dynamic and renewal times of groundwater. The use of stable and radioactive isotopes are of great interest for the development of hydrogeological models, allowing to identify water origin, water mixing, contamination processes and water residence time in aquifers (Clark, 2015).

According to Llamas and Martinez-Santos (2005) and the Global Water Partnership-GWP (Foster, 2013), irrigated agriculture worldwide is the largest user of groundwater resources, which has generated an important dependence on groundwater in agro-economies. However, the GWP also states that in many arid and drought areas, especially in the last 20–30 years, the unrestricted use of groundwater is causing serious aquifer depletion and environmental degradation. In addition, farming practices have a great influence on groundwater recharge and quality due to deforestation, irrigation modes and pollution from nutrients and pesticides. Within this context, the GWP recommends integrated studies that consider the hydrogeological settings and local agro-economic realities, so as to promote sustainable management of land and water. Taking into account that groundwater cannot be renewed artificially on a large scale, the study and sustainable management of this resource is vital.

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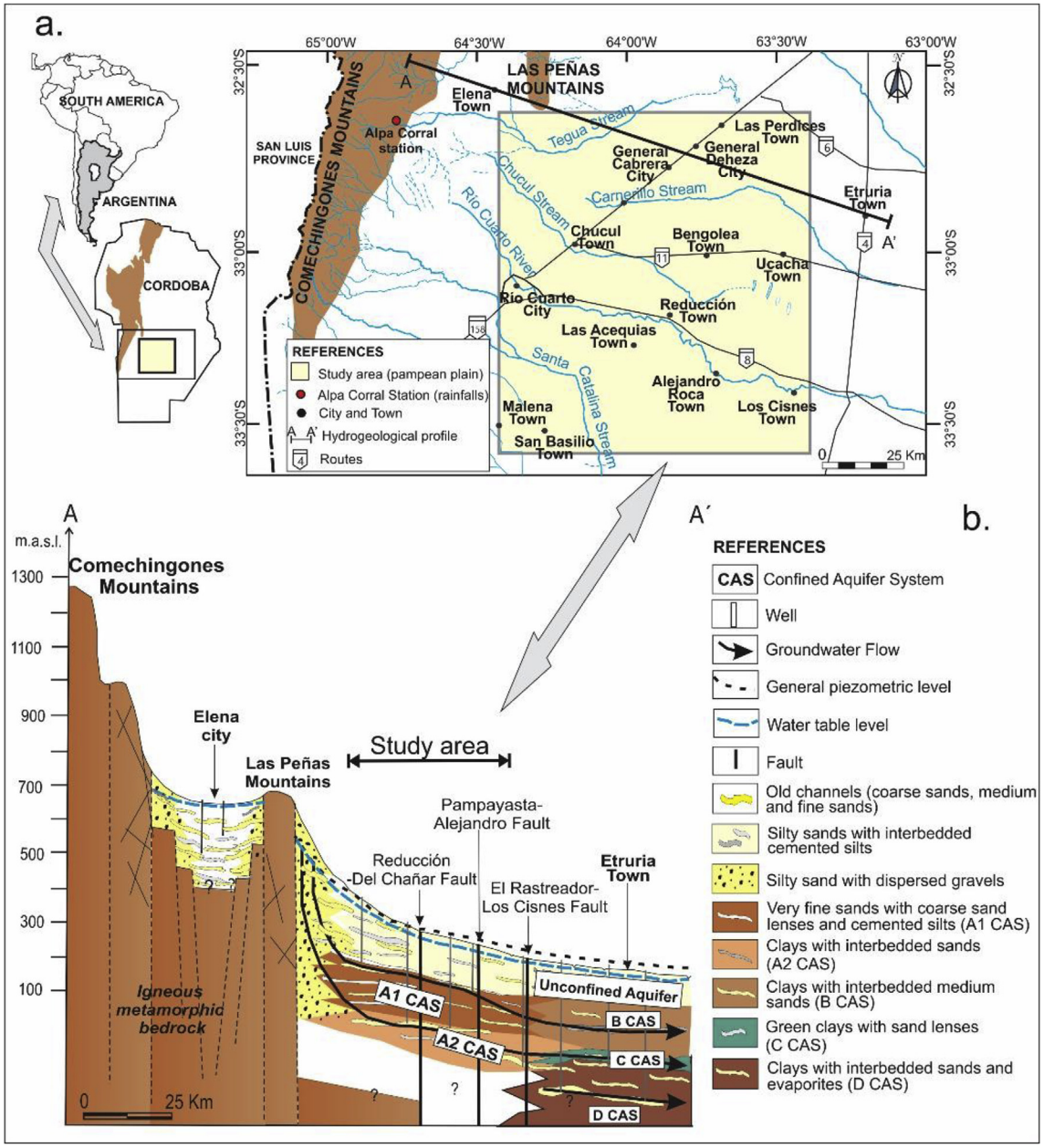

Fig. 1. a. Location of study area. b. Hydrogeological section A-A′ in the northern part of the study area (modified from Blarasin et al., 2014).

Table 1
Hydraulic parameters of the different aquifer systems (Maldonado et al., 2016).

Aquifer System			
Hydraulic Parameters	Unconfined Aquifer	A1 CAS	A2 CAS
Hydraulic Conductivity K (m/d)	10^{-3}-1	5–30	5–10
Specific Porosity ρ (%)	10–15	25	20
Hydraulic Gradient i (%)	0.10–0.20	0.35	0.30
Velocity V (m/d)	< 0.1	0.07–0.42	0.08–0.15

In the South of Córdoba province in Argentina, groundwater resources support almost all human activities, with irrigation practices as the largest water user for crops such as soybean, wheat and corn. An analysis made by Barrionuevo and Feler (2014) about irrigation systems in Córdoba province, show a remarkable increase in center pivot irrigation systems (from 2 to 1393) and irrigated areas (from 251 ha to 102,393 ha) during the 1994–2014 period. Many pivot systems use groundwater extracted from the confined aquifers, which exhibit the best chemical quality and best water yields in this region (Blarasin et al., 2014). These circumstances may generate use conflicts considering not only the Cordoba Water Law (N° 5589) gives priority to the use of water for human consumption, but also that groundwater from confined aquifers has long residence times and minimal possibility of annual recharge and water renewal from precipitation (Maldonado et al., 2016). In addition, these aquifers are mapped as discontinuous lenses and therefore may be prone to overexplotation.

The main socio-economic interest in Cordoba province is focussed on confined aquifer systems (CAS) located in the piedmont of the Pampean Mountains, particularly those named “A CAS” by Blarasin et al. (2014). This situation is based on the fact that large volumes of groundwater from each well (in the order of 100 m^3/h up to 400 m^3/h) are being extracted from these aquifer layers to be used with central pivot irrigation systems. In spite of the expansion of the irrigation area, there is not yet enough regional evidence in relation to significant water level declines. However, some local piezometric level decreases were